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The impact of waterway user charges on the United States fertilizer industry

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by

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INTRODUCTION

American agricultural exports play a key role in the American economy and international trade. During 1980, United States agricultural exports of $41.3 billion virtually compensated for a nonagricultural trade balance deficit of $48.7 billion [36, p. 5]. Figure 1 displays the moderating effect agricultural trade has had on the United States nonagricultural trade balance deficit during the 1970s; lending strength to an otherwise shaky American dollar.

Besides their obvious monetary value, United States agricultural exports are a tool used to achieve various international political goals which historically have had varying degrees of success. Loans and donations are granted through Public Law 480 and the Agency for International Development (AID) to help relieve world hunger and less nobly to make political allies. Conversely, the United States has chosen at times to not export agricultural commodities to also gain certain international political advantages. The most recent example is the United States grain embargo impose on the USSR which has yielded questionable results.

One of the key factors in the success of American agriculture has been the use of commercial fertilizers. Figure 2 shows that the use of fertilizer as an input to crop production has increased at a much faster rate than other inputs. In fact, over four times as much fertilizer is being used today as in 1940. It is estimated the United States would have needed to double its 1974 cropland acreage to produce the same crop using

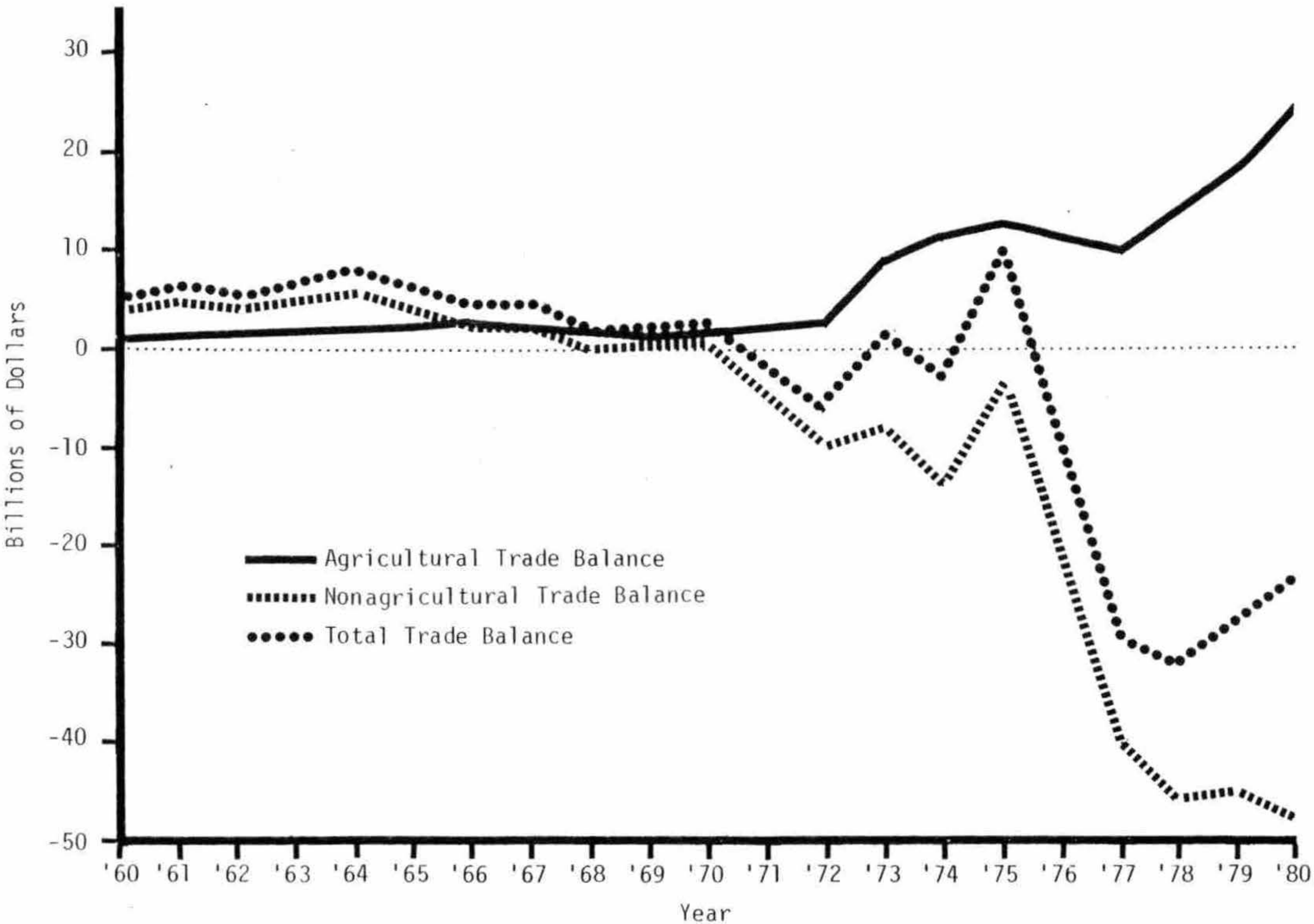

Figure 1. United States Trade Balance, 1960-1980

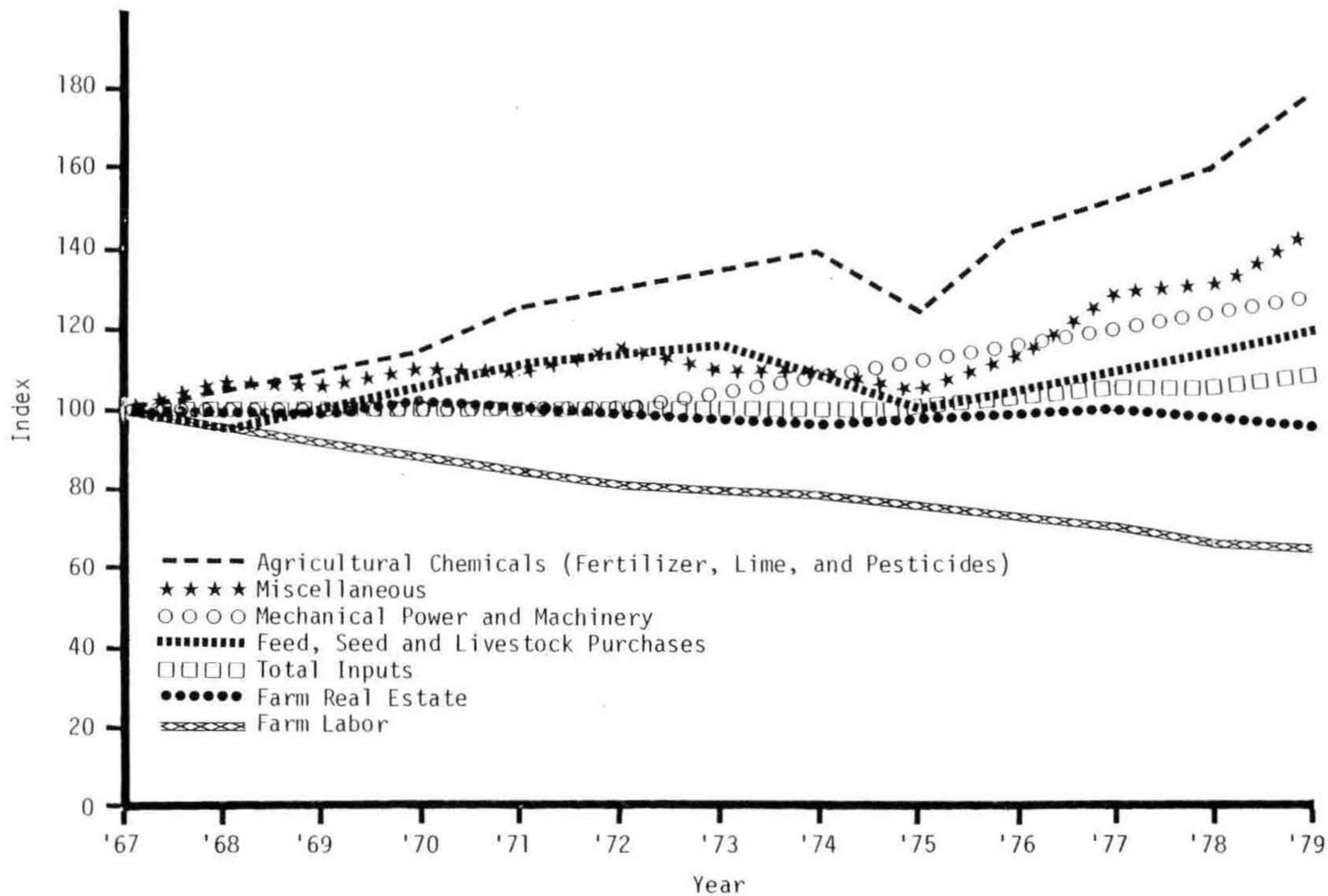

Figure 2. Index Numbers by Major Farm Input Group, 1967-1979 (1967 = 100)

the low fertilizer application levels of 1940 [26, p. 92]. However, this amount of new cropland is simply not economically available. Much of the unused land in the United States is either too dry, highly forested, or susceptible to significant erosion. If cropland acreage was not expanded and no fertilizer was applied, the United States in some instances would not have any significant agricultural production to export and possibly would be required to import small quantities of certain agricultural products [26, p. 91].[1] At the same time, rural areas might experience a depressed economy characterized by reduced retail trade, lower capital investment by farmers, and higher unemployment. Finally, it is estimated that without commercial fertilizer the United States public would spend an additional $13 billion a year on food or about $70 a year per person [23, p. 1].

Figure 3 shows that fertilizer prices have been increasing quite rapidly during the 1970s. In 1980, United States farmers paid on the average two and one-half times what they paid for fertilizer as recently as 1973. This dramatic rise in fertilizer prices has been due primarily to the steadily increasing cost of natural gas feedstocks used in the

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[1] Given that during 1979/1980, 238.2 million metric tons (MMT) of feed grains were produced, 161.0 MMT were consumed domestically, 71.3 MMT were exported, and 5.9 MMT were added to stocks on hand [33, p. 2], and assuming that 37% of all crop production is attributable to fertilizer use [26, p. 93], we find that during 1979/1980 feed grain production would drop to 150.1 MMT without the use of fertilizer. This production would not be sufficient to cover the domestic demand of 161.0 MMT, thus requiring the import of 10.9 MMT. Similar analyses can be made for other exported commodities.

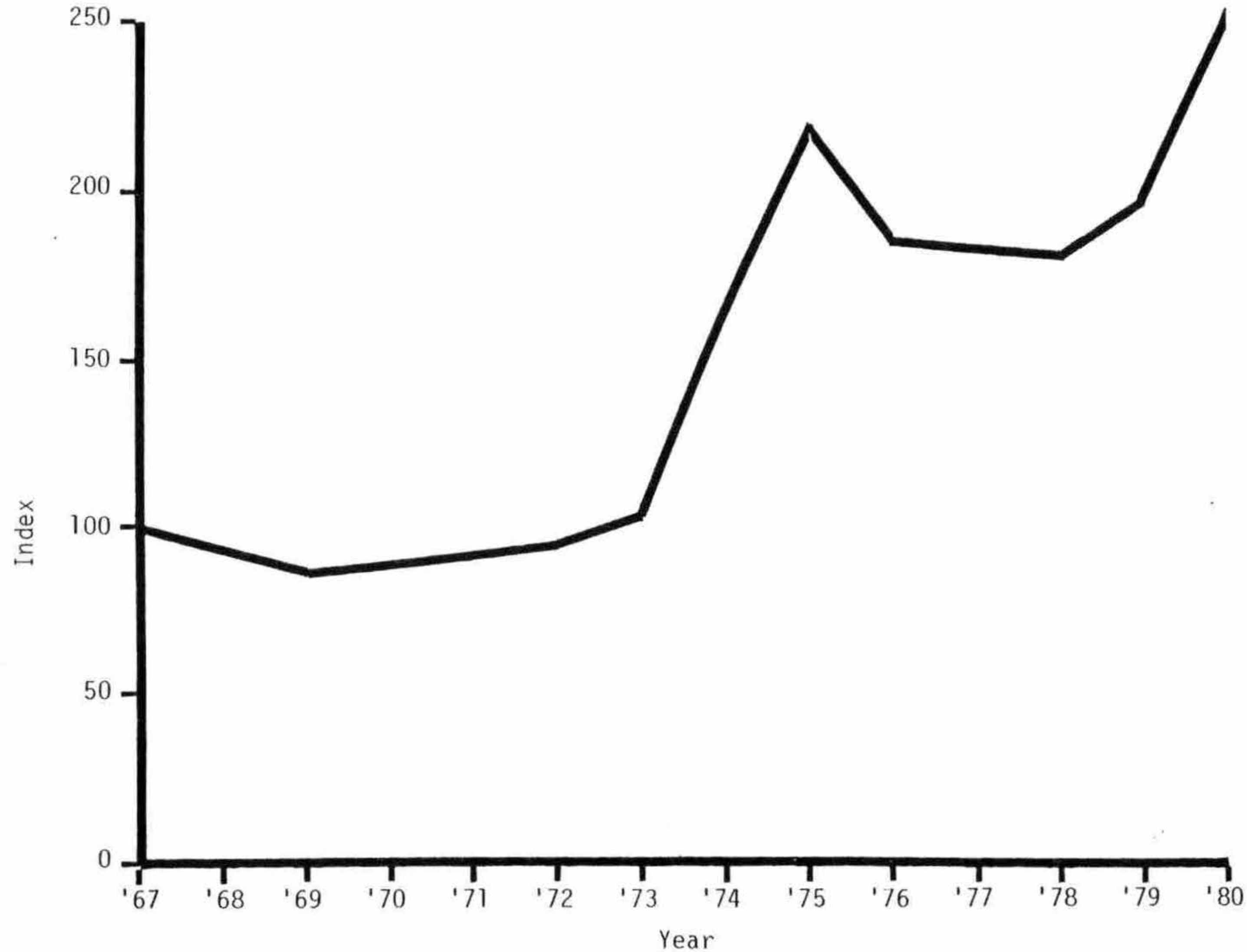

Figure 3. Index Numbers of Fertilizer Prices Paid by Farmers, 1967-1980 (1967 =100)

production of all nitrogen fertilizers, and the increasing cost of petroleum based fuels used to transport all fertilizers. Transportation's share of the total price farmers pay for fertilizer is illustrated in the following example. During March 1980, the average price farmers near Bismark, North Dakota paid for triple superphosphate fertilizer was $251 per ton [38, p. 28]. Included in this price was the transportation and handling cost of $39.03 per ton from central Florida where the production facility is located. Thus, the transportation charge was a significant amount of the total price paid by the North Dakota farmer; approximately 16%.

Obviously, the American farmer is opposed to any additional increase in the price of commercial fertilizer. An increase absorbed by the farmer reduces his net income, while an increase passed on to the American consumer stimulates inflation and provokes consumer complaints. Thus, a new potential source for increased transportation cost, waterway user charges, has generated considerable debate concerning their merits. Historically, the United States government has born the entire $5.7 billion cost of operation, maintenance, repair, and construction (OMRC) of the inland waterway system since 1824 [44, p. 16]. However, Title II of Public Law 95-502, enacted October 21, 1978, amends Chapter 31 of the Internal Revenue Code of 1954 by imposing "a tax on any liquid used during any calendar quarter by any person as a fuel in a vessel in commercial waterway transportation" [14]. This legislation as of October 1, 1980, levies a four cent per gallon fuel tax on inland barge traffic, and raises this tax in two cent increments to ten cents per gallon by 1985. Since the revenue from this tax is projected to recover only about ten to fifteen percent of the annual operating cost of the inland waterway system, the Reagan Administration has proposed further legislation to make the inland waterway system self-sufficient [18, p.76]. This legislation includes "license fees, waterway segment charges based on vessel capacity or tonnage carried, and congestion fees" [46, p.1 and 5; 22, p. 4 and 7].

These proposals have been highly criticized by members of the barge industry on the grounds that: (1) some high cost-low volume river segments such as the Missouri River would have to be closed to all commercial barge traffic with serious implications, and (2) a competitively equitable federal transportation policy should tax the railroad industry in a manner similar to the barge industry to make it self-sufficient also [29, p. 13].

Fortunately, Congress foresaw the controversy that soon enveloped waterway user charge legislation and authorized $8 million to:

> . . . (1) make a full and complete study with respect to inland waterway user taxes and charges, and . . . (2) make findings and policy recommendations with respect thereto . . . .[14]

Some key issues to be studied include:

> . . . the economic effects of waterway user taxes and charges on . . . carriers and shippers using the inland waterways, and . . . users (including ultimate consumers) of commodities which are transported on the inland waterways, and . . . competitors--on the freight rates charged by other modes of transportation and the extent of short-term and long-term diversion of traffic from the inland waterways to such other modes . . . .[14]

Finally, the Secretary of Transportation is required to submit to Congress not later than September 30, 1981, a final report of the study "together with his findings and recommendations (including necessary legislation)" [14]. Iowa State University is one of several institutions contracted to perform portions of this study, providing the Secretary of Transportation with input to compile his Congressional report. This thesis is based on Iowa State University's research efforts.

OBJECTIVE

The objective of this study is to investigate the impact of various types and levels of waterway user charges levied on the projected 1985 and 1990 fertilizer transportation industries.

The impact of waterway user charges is analyzed through computer modelling techniques, which provide the following information for analysis of each waterway user charge scenario:

- Barge, rail, truck, and pipeline modal shares by fertilizer, market, and production facility
- Fertilizer market patterns by fertilizer, market, production facility, and mode of transport
- Total cost of fertilizer distribution by fertilizer, market, production facility, and mode of transport
- Tax collected by type of fertilizer and river
- Total revenue collected by mode of transport

By comparing these data for each user charge scenario, one is able to develop meaningful conclusions concerning the relative impact each scenario has upon various sectors of the fertilizer industry.

LITERATURE REVIEW

The waterway user charge issue is quite new to transportation economics. Several studies have been conducted to investigate the impacts of user charges on the grain industry, but very little in-depth research has been performed with respect to the fertilizer industry. Consequently, virtually no literature has been published on the impact of waterway user charges on fertilizer manufacturers, consumers, and shippers. The small amount of fertilizer literature that is available is reviewed below.

Bunker [3], in 1976, studied the impacts of waterway user charges on Logan county in central Illinois. A linear programming model was constructed to examine the effects of user charges on the total cost of marketing grain and fertilizer, modal utilization, spatial distribution patterns, road and highway use, and revenue generated. It was found that user charges recovering all operation and maintenance costs of the inland waterway system had very little impact on the fertilizer industry in Logan county, Illinois.

In 1981, the Minnesota Department of Transportation [19] analyzed the impact of waterway user charges on Minnesota's economy. This study examined the effects of different types of user charges designed to recover various levels of operation and maintenance cost of the inland waterway system. It was determined that the greatest impact of user charges was in the agricultural sector. In the case of fertilizer, it was estimated that a 4¢ per gallon fuel tax would increase total fertilizer transportation costs by a quarter of a million dollars in 1980.

Even though many other fertilizer marketing studies do not specifically address the waterway user charge issue, they easily could. Many of the models used in these studies are based on regional supplies and demands for fertilizer, linked by a set of transportation rates which allow fertilizer to flow from supply regions to demand regions. Often waterway user charges can be incorporated into these models relatively easily by adding the user charge to the appropriate barge rates.

The Reagan Administration's stance on the user charge issue has generated quite a debate in the transportation industry. Examining the popular transportation literature, one finds a wide range of opinions and arguments both for and against user charges. Therefore, Congress has initiated several studies, including one on which this thesis is based, to investigate the impacts of waterway user charges and provide Congress with input that will allow it to make sound user charge policy decisions. Many of these studies are nearing completion and will probably generate more user charge literature than is currently published.

METHOD OF ANALYSIS

Early Relationship of Linear Programming and Transportation

Linear programming techniques have been applied to transportation problems since the late 1940s. Theoretically, linear programming is a simple concept involving the maximization (or minimization) of an objective function subject to a set of resource constraints. Determining whether or not to maximize or minimize an objective function depends on the nature of the problem. In most economic applications, either profit is maximized or cost is minimized. Thus, in this waterway user charge study, the objective function being minimized is the total transportation and handling costs of five fertilizers in the United States. This objective function is subject to fertilizer supply and demand (i.e., resource) constraints for the United States.

Kantorovich [16], a Russian, published the first literature on linear programming in 1939. In his book he gave an algorithm for solving linear programming problems and suggested that such techniques could be efficiently applied to centrally planned economies such as that in Russia. However, Kantorovich's work went unnoticed by the Americans till the late 1940s.

The transportation problem was first presented as a special area of linear programming in 1941 by Hitchcock [11]. Later in 1947, Koopmans

[17] presented a much deeper theoretical discussion of the transportation problem.

Finally, Danzig [5] working for the United States Department of the Air Force in 1947, made a key breakthrough by developing a systematic iterative technique of solving linear programs. This technique is called the simplex method. The Air Force extended and applied Danzig's work to military problems by organizing Project SCOOP (Scientific Computation of Optimum Programs). One of their first linear programming applications occurred during the Berlin airlift [8, p. 15] of 1948-1949. The objective was to maximize the number of tons of material reaching Berlin subject to available runways, crews, aircraft, and money.

As one can see, it took a very short time for the relationship between linear programming and transportation problems to develop. For several years though, finding solutions to transportation linear programs was a slow tedious process performed entirely by hand calculation. Some computational short cuts were soon discovered, but it was not until January 1952, when the first successful solution of a linear program was achieved on a high speed digital computer, that linear programming became a tool to apply to large scale problems. Since that time, developments in computer hardware technology have dramatically increased computational speed and problem size. At the same time, computer software developments have optimized computing algorithms and simplified data input for the researcher to the point that linear programming applications are virtually unlimited.

Verbal Description of the Model

The impacts of various types of waterway user charges on the projected 1985 and 1990 United States fertilizer industries are modelled through linear programming techniques. The model minimizes total transportation and handling costs of shipping five major fertilizers from 46 supply points to 84 demand regions in meeting agricultural fertilizer demand. These fertilizers are urea, ammonium nitrate, ammoniated phosphates, triple superphosphate, and nitrogen solutions. The location of supply points and demand regions relative to the inland waterway system are given in Map 1. Since very little fertilizer is shipped across the Rocky Mountains, only demand regions and supply points east of the Rockies are included in this model. Each demand region consists of one or more crop reporting districts (CRDs) depending on its size, agricultural importance, and proximity to the inland waterway system, and is identified by a single retail fertilizer dealer in that demand region. In theory, all retail fertilizer dealers in the demand region are operating competitively, but only one is chosen as a representative for identification and transportation cost calculation purposes.

The following basic assumptions are imposed on the model:

- Contractual agreements, corporate identity, and other relationships within and among fertilizer manufacturers, retail dealers, and the transportation industry are not modelled. These relationships are difficult and expensive to

Map 1. Fertilizer supply point and demand region locations

model and in many cases are even more difficult to properly identify.

- o Sufficient quantities of primary inputs such as anhydrous ammonia, nitric acid, phosphate rock, phosphoric acid, sulphuric acid, and water are available to manufacture the fertilizers modelled in this study.
- o For a given type of fertilizer the same price is quoted at all supply points. Thus, fertilizer prices are not a factor in this model.
- o Fertilizer shipped to demand regions during a fiscal year ending June 30 is applied to crops which will be harvested during the next fiscal year.
- o Each type of fertilizer is a homogeneous material.

Agricultural fertilizer demand is estimated for each demand region for five selected nitrogen (N) and phosphate (P_2O_5) fertilizer materials as described in the DATA section. These fertilizer materials are urea, ammonium nitrate, ammoniated phosphates, and triple superphosphate--dry fertilizers and nitrogen solutions a liquid fertilizer. The demand for potassium (K_2O) fertilizer materials has not been modelled since virtually all K_2O fertilizer materials are mined and processed in the western United States or Canada, too distant from the inland waterway system to utilize it effectively. Nonagricultural demand is estimated for urea and ammonium nitrate which are inputs for other manufactured products such as plastics, livestock feed additives, and explosives. The supply of these materials for agricultural use is reduced by their estimated nonagricultural demand as described in the DATA section. Export demand is the final type of fertilizer demand in which we are interested. The model does not endogenously allocate any fertilizer for export. It simply assumes that after domestic needs have been satisfied, any excess United States production capacity is available for export.

Fertilizer supply points include all those facilities producing urea, ammonium nitrate, nitrogen solutions, ammoniated phosphates, or triple superphosphate in the United States and Canada. The supply of fertilizer at some Canadian production facilities is reduced a priori to any modelling to account for Canadian consumption. Also, included as supply points are any ports importing significant quantities of fertilizer. All of these imports are of a non-Canadian origin since very little Canadian fertilizer is shipped in ocean going vessels to any of the demand regions delineated by this study.

Nitrogen solutions create a special problem in this model. One of the most common types of nitrogen solutions is manufactured from urea, ammonium nitrate, and water; inputs of which most supply points have an adequate supply to meet maximum nitrogen solutions production capacity. However, those supply points which are potentially deficient in nitrogen solutions inputs are given the option of receiving those inputs from other supply points. Thus not all fertilizer shipments in this model move directly from supply points to demand regions. Some urea and ammonium nitrate may be transshipped through nitrogen solutions production facilities before reaching demand region destinations as nitrogen solutions. Finally, any nitrogen solutions imported to the United States do not require any manufacturing in the United States. It is assumed the manufacture and associated consumption of raw materials is exogenous to the model.

Fertilizer is shipped from supply points to demand regions or other supply points by the following modes: rail, truck, barge-rail, barge-truck, pipeline-rail, and pipeline-truck. Rail and truck modes are available for all fertilizers, with the restriction that the truck mode is available only on shipments which travel less than 300 miles. The barge-rail and barge-truck modes are combination modes available to all fertilizers except ammonium nitrate which can be extremely hazardous if not handled properly in moist situations. Also all urea, ammoniated phosphates, and triple superphosphate shipped as a barge combination mode must pass through one of 21 river warehouses along the inland waterway system. Likewise, all nitrogen solutions shipped as a barge combination mode must pass through one of 20 river tank terminals along the inland waterway system. The pipeline-truck and pipeline-rail modes are combination modes available only to nitrogen solutions, with the requirement that all nitrogen solutions shipped as a pipeline combination mode must pass through one of 18 pipeline tank terminals.

This model is subject to two other rather obvious modal restrictions. First, barge combination shipments must originate in either southern Louisiana or central Florida with access to the inland or coastal waterway systems. Similarly, pipeline combination shipments must originate from fertilizer production facilities located on the liquid fertilizer pipeline as fertilizer injection points. A consequence of these modal restrictions is that different supply point-demand region and supply point-supply point pairs do not necessarily have the same set of modes available for use. In some cases only one mode, rail, is available while in other cases up to four modes, rail, truck, and either the barge combination, or pipeline combination modes are available.

Some linear programming transportation models allow each supply point the option of shipping to every demand region. However, this technique often leads to the inclusion of many nonsensical supply point-demand region pairs which only increase the size and expense of the model. Thus, in the interest of building an inexpensive yet sound model, only a subset of all supply point-demand region pairs are included in this fertilizer model. Supply points with a relatively small production capacity and who have historically shown a strong tendency of shipping their product for local consumption,[2] are usually given the option of shipping to a set of surrounding demand regions whose aggregate demand is three or four times the supply points production capacity. This gives the supply point considerable latitude in choosing where to market its fertilizer locally while keeping the model relatively small. Those supply points which are major producers of a particular fertilizer, marketing it nationwide, are still given the option of shipping to all demand regions. Since there are only a few of these national marketing supply points, the model remains relatively small without sacrificing any accuracy.

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[2] Historical market shares are discerned from industry contacts and a marketing study conducted by The Fertilizer Institute [47].

Associated with each potential mode for a given supply point-demand region or supply point-supply point pair is the transportation and handling cost for each type of fertilizer manufactured at the supply point. These costs are the basis for determining an optimum fertilizer transportation network. The model simultaneously satisfies demand for all fertilizers while minimizing total transportation and handling costs subject to a set of resource constraints. These constraints are:

- Annual agricultural demand for each type of fertilizer in each demand region must be satisfied.
- Annual nonagricultural demand for urea and ammonium nitrate must be satisfied.
- The quantity of fertilizer shipped from a given supply point can not exceed the annual production or import capacity of the supply point for each type of fertilizer.
- The total quantity of urea, ammoniated phosphates, and triple superphosphate passing through each river warehouse location can not exceed each location's annual throughput capacity.
- A minimum quantity of nitrogen solutions must pass through each pipeline tank terminal annually. These pipeline tank terminals as well as river warehouses and river tank terminals act as buffers alleviating some of the strain on the fertilizer transportation system in the spring when the rail system is operating at capacity.

o The total quantity of nitrogen solutions passing through each pipeline tank terminal can not exceed each locations annual throughput capacity.

Once a sound base solution has been obtained, various types of waterway user charges can be modelled by simply reflecting these charges in the fertilizer barge rates. Optimum transportation networks are derived for each user charge scenario and the results compared. In some cases rail, truck, and/or pipeline rates are also adjusted to simulate how competing transportation modes might respond to a particular type of waterway user charge. Each waterway user charge scenario is discussed more thoroughly in the DATA section.

Inevitably, the question arises concerning who will pay for the various user charge taxes; the barge industry or the farmer. This study assumes that the barge company will pass the tax forward to the fertilizer buyer in the form of a higher price for barge service. Technically, the types of user charges examined in this study are specific excise (i.e., per unit) taxes which are a function of the quantity of the commodity or service sold. Economic theory states that even though the excise tax is levied on the seller of the service, the seller may pass the tax on to the buyer in the form of a higher price. The ability of the seller to pass the tax on while maximizing his total revenue depends on the elasticity (i.e., sensitivity) of supply and demand to changes in price. For example, Figure 4 hypothetically illustrates user charge tax effects on both the buyer and seller of fertilizer barge service given a relatively inelastic demand by the buyer. The original supply and demand curves for

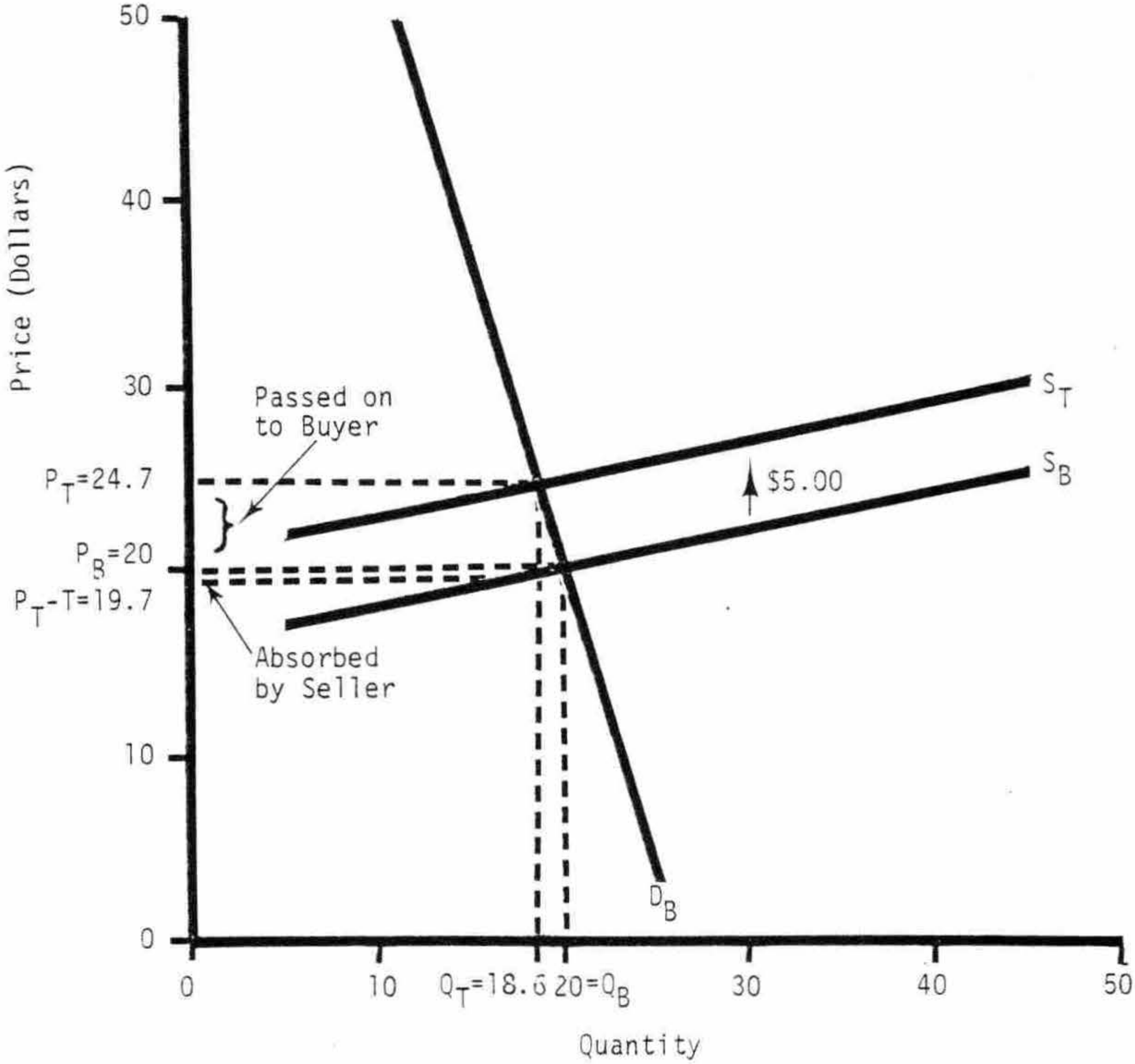

Figure 4. Distribution of a $5.00 per unit User Charge Tax to the Buyer and Seller of Fertilizer Barge Service in an Inelastic Demand Situation

fertilizer barge service in the no user charge (i.e., base) situation are denoted by S_B and D_B respectively, with P_B = \$20.00 and Q_B = 20.0 being the associated equilibrium price and quantity. Now lets assume a \$5.00 user charge tax is levied on the barge industry such that the seller of the barge service is the one who must actually pay the tax. The seller feels he must receive \$5.00 per unit more for service, thus shifting his supply curve upward \$5.00. The new equilibrium point in the market is the intersection of D_B and S_T, where P_T = \$24.70 and Q_T = 18.60.

It is now possible to determine the seller's ability to pass on the user charge tax to the buyer. In this example, the seller is able to pass on most of the \$5.00 tax, $P_T - P_B$ = \$4.70, while absorbing only $P_B - (P_T - T)$ = \$0.30. Such is the case when demand is inelastic. In fact, in the extreme case where demand is totally inelastic, the seller is able to pass on all of the tax without losing any of his share of the market.

Mathematical Model

The objective of this model is to minimize total transportation and handling costs in satisfying fertilizer demand for the 84 demand regions delineated in this study (1).

$$\text{Minimize } Z = \sum_{sdfm}\sum\sum\sum T_{sdfm} \cdot A_{sdfm} + \sum_{sdfmr}\sum\sum\sum\sum U_{sdfmr} \cdot B_{sdfmr} +$$

$$\sum_{ssfm}\sum\sum\sum V_{ss'fm} \cdot C_{ss'fm} + \sum_{sdfmp}\sum\sum\sum\sum W_{sdfmp} \cdot P_{sdfmp} \quad (1)$$

where

Z = Total annual fertilizer transportation and handling costs

T_{sdfm} = Tons of fertilizer f, shipped by mode m, directly from supply point s, to demand region d

A_{sdfm} = Transportation and handling cost of shipping fertilizer f, by mode m, directly from supply point s, to demand region d

U_{sdfmr} = Tons of fertilizer f, shipped by mode m, through river warehouse or tank terminal r, from supply point s, to demand region d

B_{sdfmr} = Transportation and handling cost of shipping fertilizer f, by mode m, through river warehouse or tank terminal r, from supply point s, to demand region d

$V_{ss'fm}$ = Tons of fertilizer f, shipped by mode m, directly from supply point s, to supply point s'

$C_{ss'fm}$ = Transportation and handling cost of shipping fertilizer f, by mode m, directly from supply point s, to supply point s'

W_{sdfmp} = Tons of fertilizer f, shipped by mode m, through pipeline tank terminal p, from supply point s, to demand region d

P_{sdfmp} = Transportation and handling cost of shipping fertilizer f, by mode m, through pipeline tank terminal p, from supply point s, to demand region d

The following constraints are imposed on the model to satisfy fertilizer demands, limit fertilizer supplies, and limit warehouse and tank terminal throughput.

Estimated annual agricultural fertilizer demand must be satisfied for each demand region (2).

$$\sum_{s}\sum_{m} T_{sdfm} + \sum_{s}\sum_{m}\sum_{r} U_{sdfmr} + \sum_{s}\sum_{m}\sum_{p} W_{sdfmp} >= D_{df}, \text{ for all combinations of d and f} \qquad (2)$$

where

D_{df} = The demand for fertilizer f, in demand region d

Non-agricultural fertilizer demand must be satisfied (3).

$$\sum_{s} X_{sf} = N_f, \text{ for f = urea and ammonium nitrate} \qquad (3)$$

where

X_{sf} = The quantity of fertilizer f, allocated to non-agricultural uses at supply point s

N_f = Total non-agricultural demand for fertilizer f

The quantity of each type of fertilizer shipped from a supply point can not exceed estimated annual production capacity plus imports for that fertilizer (4).

$\sum_{dm}\sum T_{sdfm} + \sum_{dmr}\sum\sum U_{sdfmr} + \sum_{s'}\sum_{m} V_{ss'fm} + \sum_{dmp}\sum\sum W_{sdfmp} + X_{sf} <= S_{sf}$, for all combinations of s and f (4)

where

S_{sf} = Aggregate annual production capacity and imports for fertilizer f, at supply point s

A minimum quantity of fertilizer must pass through each pipeline tank terminal (5).

$\sum_{sdfm}\sum\sum\sum W_{sdfmp} >= H_p$, for all combinations of f = nitrogen solutions and p (5)

where

H_p = The minimum quantity of fertilizer f, that must pass through pipeline tank terminal p

The quantity of fertilizer passing through each river warehouse and river tank terminal can not exceed each location's annual throughput capacity (6 and 7).

$\sum_{sdfm}\sum\sum\sum U_{sdfmr} <= L_r$, for all combinations of f = urea, ammoniated phosphates, and triple superphosphate and r (6)

$\sum_{sdfm}\sum\sum\sum U_{sdfmr} <= M_r$, for all combinations of f = nitrogen solutions and r (7)

where

L_r = The maximum annual throughput capacity of river warehouse r

M_r = The maximum annual throughput capacity of river tank terminal r

The quantity of fertilizer passing through each pipeline tank terminal can not exceed each location's annual throughput capacity (8).

$$\sum_{s}\sum_{d}\sum_{f}\sum_{m} W_{sdfmp} <= K_p, \text{ for all combinations of } f = \text{nitrogen solutions and } p \tag{8}$$

where

K_p = The maximum annual throughput capacity of pipeline tank terminal p

All activity levels must be non-negative (9).

$$T_{sdfm}, U_{sdfmr}, V_{ss'fm}, W_{sdfmp} >= 0 \tag{9}$$

All transportation and handling cost coefficients must be negative (10).

$$A_{sdfm}, B_{sdfmr}, C_{ss'fm}, P_{sdfmp} < 0 \tag{10}$$

All constraint coefficients must be non-negative (11).

$$D_{df}, X_{sf}, N_f, S_{sf}, H_{fp}, L_r, M_r, K_p >= 0 \tag{11}$$

DATA

Data requirements for this fertilizer model fall into the following four general categories: fertilizer supply, demand, warehouse and tank terminal capacities, and transportation and handling costs. The model minimizing 1985 fertilizer transportation and handling costs is constrained by 1985 fertilizer supplies and demands while the model minimizing 1990 fertilizer transportation and handling costs is constrained by 1990 fertilizer supplies and demands. Also included in the DATA section is a discussion of each user charge scenario modelled in this study.

Estimated 1985 Fertilizer Supplies

Tables 1 and 2 present estimated 1985 fertilizer supplies which this study splits into two categories; North American production and non-North American imports. Estimated 1985 production capacities are identified for each North American facility manufacturing urea, ammonium nitrate, nitrogen solutions, ammoniated phosphates, and triple superphosphate through unpublished data provided by the Tennessee Valley Authority (TVA) [28]. Additional data published by the British Sulphur Corporation [20; 21] were used to verify the TVA production capacities. Included among these data are the production capacities of any facilities currently idle

Table 1

Estimated 1985 and 1990 Fertilizer Production Capacities by Origin (Thousands of Tons)

Location[a]	Ammonium Nitrate	Urea	Nitrogen Solutions	Ammonium Phosphate	Triple Superphosphate
Birmingham, AL	16				
Cherokee, AL	133	154	150	200	
Muscle Shoals, AL					
El Dorado, AR	537				
Sterlington, LA					
Bartow, FL	184		446	5,102	3,969
Tampa, FL					
Pierce, FL					
Piney, Point, FL					
Bonnie, FL					
Plant City, FL					
Nichols, FL					
Mulberry, FL					
Ft. Mead, FL					
White Springs, FL				640	170
Augusta, GA	568	410	680		

[a] For modelling purposes, indented locations are represented by the first location in each group.

Table 1-Continued

Location[a]	Ammonium Nitrate	Urea	Nitrogen Solutions	Ammonium Phosphate	Triple Superphosphate
Bainbridge, GA	51		168		
Savannah, GA	283	110	329		
Marseilles, IL Seneca, IL Du Pue, IL	393		170	448	
Terre Haute, IN	175		50		
Clinton, IA East Dubuque, IL	229	186	405		
Ft. Dodge, IA		70			
Ft. Madison, IA	100		165	359	
Sergeant Bluff, IA	160	255	238		
Lawrence, KS	270	266	250		
Brandon, MB	92		127		
Donaldsonville, LA Taft, LA Geismar, LA Luling, LA	902	1,821	1,510	2,530	
Pine Bend, MN	230		80		

Table 1-Continued

Location[a]	Ammonium Nitrate	Urea	Nitrogen Solutions	Ammonium Phosphate	Triple Superphosphate
Courtright, ON Dearborn, MI	145	125	166	21	
Pascagoula, MS Pace Junction, FL	200	23	65		274
Yazoo, City, MS	550	153	450		
Crystal City, MO	100		105		
Louisiana, MO Hannibal, MO	632	95	290		
Beatrice, NE	243	56	158		
La Platte, NE Fremont, NE	233	195	524		
Philadelphia, PA Gibbstown, NJ Tamaqua, PA	90				
Olean, NY Welland, ON	228	140	155		
Belledune, NB			160		
Lee Creek, NC				213	553

Table 1-Continued

Location[a]	Ammonium Nitrate	Urea	Nitrogen Solutions	Ammonium Phosphate	Triple Superphosphate
Wilmington, NC	188		198		
Lima, OH	85	238	140		
North Bend, OH	96				
Verdigris, OK Pryor, OK Joplin, MO Pittsburg, KS	1,414	597	1,451		98
Woodward, OK Dodge City, KS	186	83	445		
Donora, PA	137				
Tyner, TN	245	45	100		
Woodstock, TN Blytheville, AR Helena, AR	96	805	90		
Borger, TX Etter, TX Dimmitt, TX	205	109	90		
Odessa, TX Hobbs, NM Carlsbad, NM	50	88	18		

Table 1-Continued

Location[a]	Ammonium Nitrate	Urea	Nitrogen Solutions	Ammonium Phosphate	Triple Superphosphate
Pasadena, TX	177	219	177	480	
Beaumont, TX					
Lake Charles, LA					
Tunis-Ahoskie, NC	300	165	471		
Cheyenne, WY	38	25	28		
Maitland, ON	219	11	74		
Beloeil, PQ					
McMasterville, PQ					
Carseland, AB	27	685	20	50	
Medicine Hat, AB					
Calgary, AB					
Ft. Saskatchewan, AB					
Redwater, AB					
Kimberly, BC					
Trail, BC					
Total	10,207	7,129	9,983	10,230	5,064

Table 2

Estimated 1985 Non-North American Fertilizer Imports by Port of Entry (Thousands of Tons)

Location[a]	Ammonium Nitrate	Urea	Nitrogen Solutions
Tampa, FL			10
Savannah, GA Charleston, SC		42	27
New Orleans, LA	5	444	22
Philadelphia, PA Baltimore, MD	28	76	65
Wilmington, NC		148	62
Cleveland, OH	12	104	10
Pasadena, TX	7		43
Norfolk, VA	15		97
Duluth, MN	7		
Total	73	814	336

[a] For modelling purposes, indented locations are represented by the first location in each group.

but capable of resuming operations on short-term notice as dictated by the economic conditions of the fertilizer industry.

In a few situations, fertilizer production capacities must be modified to correct modelling problems. For example, fertilizer plants located in Odessa, Texas; Hobbs, New Mexico; and Cheyenne, Wyoming, market approximately half of their production outside the study area of the model. Thus, it is assumed that only half of these plants production is available for consumption in the study area. Also, Canadian fertilizer production capacities are reduced to account for domestic Canadian consumption.

The other source of fertilizer supply, non-Canadian imports is estimated from United States Department of Agriculture (USDA) data [31]. Time series trends from 1961 to 1978 are used to estimate total 1985 non-Canadian fertilizer imports for urea, ammonium nitrate, and nitrogen solutions. United States Department of Commerce (USDC) data [41] are used to identify fertilizer imports by the quantity of fertilizer passing through each United States customs district by country of origin. Since Canadian fertilizer production has been accounted for as North American production, Canadian fertilizer imports are removed from these USDC data. Likewise, insignificant quantities of imported non-Canadian phosphate materials are ignored also. Thus, the remainder of this discussion concerning fertilizer imports focuses on non-Canadian imports of the nitrogen materials, urea, ammonium nitrate, and nitrogen solutions.

Major fertilizer importing customs districts (i.e., ports) are identified by first averaging the quantity of each type of fertilizer passing through each customs district during the three year period from 1975 to 1977. For each fertilizer, customs districts are then ranked by their three year average. Beginning with the largest importer of each fertilizer, import volume is summed until 90% of total imports are accounted for. Those ports contained within the 90% group for a particular fertilizer are considered significant importers. It should be noted that the 90% summation limit is an arbitrary cut off point used to eliminate numerous small volume importers who only complicate the model while contributing very little to it.

Estimated 1985 non-Canadian fertilizer imports are allocated to significant importers based on each importer's historical share. For example, if New Orleans, Louisiana imported 20% of all non-Canadian urea during 1975-1977, New Orleans is allocated 20% of estimated 1985 non-Canadian urea imports also. Finally, as with North American supply points, those ports west of the Rocky Mountains are removed from this study since very little fertilizer is shipped across the mountains.

Estimated 1990 Fertilizer Supplies

Tables 1 and 3 present estimated 1990 fertilizer supplies which change very little from estimated 1985 fertilizer supplies. Industry contacts indicate that little, if any, additional North American production capacity will be coming on-line between now and 1990. The primary barrier to future expansion is the constantly increasing cost of natural gas. In 1973, producers paid an average of only $0.36 per

Table 3

Estimated 1990 Non-North American Fertilizer Imports by Port of Entry (Thousands of Tons)

Location[a]	Ammonium Nitrate	Urea	Nitrogen Solutions
Tampa, FL			12
Savannah, GA Charleston, SC		51	33
New Orleans, LA	6	542	27
Philadelphia, PA Baltimore, MD	35	92	79
Wilmington, NC		181	75
Cleveland, OH	15	126	12
Pasadena, TX	9		51
Norfolk, VA	19		118
Duluth, MN	8		
Total	92	992	406

[a] For modelling purposes, indented locations are represented by the first location in each group.

thousand standard cubic feet (s.c.f.) of natural gas, while in 1980 the average price paid rose to \$1.86 per thousand s.c.f. [48]. Producers expect their costs to continue to rise as many long term, fixed price gas contracts negotiated in the 1960s expire and government decontrol of natural gas is completed by January 1985. New gas contracts will need to be negotiated at rates many producers fear may be as high as \$6.00-\$7.00 per thousand s.c.f.; an obvious deterrent to new construction. In fact, one industry contact is so pessimistic, he believes some nitrogen production capacity may become idle during the mid or late 1980s. As a consequence, any additional nitrogen fertilizer demand will probably be satisfied by increased imports and reduced exports.

Non-Canadian fertilizer imports for 1990 are estimated by using the same procedure as 1985 non-Canadian imports. The only modification in the procedure is that historical shares are used to allocate 1990 rather than 1985 total imports of urea, ammonium nitrate, and nitrogen solutions to significant importers.

Estimated 1985 Agricultural Fertilizer Demand

Table 4 presents estimated 1985 nitrogen (N) and phosphate (P_2O_5) agricultural fertilizer demand by type of fertilizer material for each demand region. Nitrogen fertilizer materials consist of anhydrous ammonia, urea, ammonium nitrate, nitrogen solutions, and all other nitrogen materials, while phosphate fertilizer materials are defined as

Table 4

Estimated 1985 Nitrogen and Phosphate Fertilizer Material Demand

Demand Region	Ammonium Nitrate	Nitrogen Solutions	Urea	Ammonium Phosphate	Triple Superphosphate
1	135,564	89,316	30,676	57,534	72,840
2	168,472	139,155	33,908	61,355	67,002
3	17,428	17,916	48,705	33,760	28,889
4	41,520	42,240	108,771	46,617	45,646
5	28,991	21,869	146,626	25,274	19,822
6	14,295	9,292	28,226	4,323	17,385
7	12,907	18,858	66,178	56,634	14,093
8	18,824	170,775	25,800	113,899	34,696
9	196,275	307,063	20,454	68,040	80
10	66,106	352,610	1,633	111,994	31,863
11	66,561	355,025	1,644	112,763	32,078
12	6,806	99,434	26,011	111,826	32,500
13	6,523	95,341	30,261	122,353	32,908
14	6,450	117,279	43,452	150,311	31,755
15	6,000	87,644	22,926	116,923	33,983
16	7,669	112,041	29,309	132,819	38,602
17	7,299	106,616	27,889	151,811	44,122
18	5,113	74,719	19,546	127,727	37,122
19	4,027	58,832	15,389	98,697	28,687
20	313	155,187	10,704	117,865	62,008
21	253	125,929	8,685	107,789	56,709
22	257	127,225	8,774	100,462	52,852
23	466	118,647	38,415	115,273	62,052
24	59,809	115,684	26,520	120,049	58,935
25	38,744	62,063	16,300	106,302	51,687
26	2,510	67,044	34,398	124,339	16,396
27	3,021	80,638	41,372	145,210	19,148
28	2,442	71,754	52,324	173,120	16,324

Table 4--Continued

Demand Region	Ammonium Nitrate	Nitrogen Solutions	Urea	Ammonium Phosphate	Triple Superphosphate
29	2,976	79,506	40,791	127,111	16,761
30	2,955	78,938	40,498	134,280	17,707
31	2,116	56,506	28,991	99,650	13,139
32	36,194	82,890	45,366	84,991	42,756
33	982	26,203	13,443	38,584	5,087
34	12,498	37,747	10,328	24,998	1,602
35	24,158	72,956	19,965	85,569	5,492
36	22,107	66,765	18,271	94,889	6,089
37	21,803	65,847	18,017	40,864	2,622
38	19,907	60,119	16,450	85,084	5,459
39	26,543	53,349	22,822	103,204	32,398
40	67,290	40,153	28,793	90,093	43,483
41	36,251	59,737	31,455	83,589	41,416
42	16,574	30,691	17,430	61,300	29,316
43	64,047	39,897	54,191	10,841	94,873
44	2,408	38,377	28,504	82,194	12,508
45	1,992	17,794	14,091	32,521	12,671
46	14,329	127,994	101,355	233,925	91,143
47	743	30,278	40,270	121,861	5,698
48	687	27,944	37,167	112,472	5,259
49	663	26,966	35,863	108,526	5,074
50	4,540	37,904	41,229	114,829	6,252
51	878	35,741	47,537	143,855	6,726
52	54,044	36,163	45,538	16,560	22,817
53	67,358	82,422	47,800	88,278	97,202
54	36,513	44,679	25,911	51,313	56,498
55	7,051	52,818	10,326	72,474	7,995
56	9,528	66,312	15,222	90,838	9,911
57	8,018	74,694	8,143	56,766	6,437

Table 4--Continued

Demand Region	Ammonium Nitrate	Nitrogen Solutions	Urea	Ammonium Phosphate	Triple Superphosphate
58	14,651	136,509	14,885	76,790	8,709
59	12,123	112,966	12,315	71,768	8,140
60	9,904	92,269	10,061	45,413	5,150
61	1,646	111,766	97,833	60,784	78,345
62	7,694	96,081	25,949	2,641	21,532
63	23,594	191,566	1,974	64,393	44,409
64	45,433	368,897	3,800	92,215	63,597
65	950	23,282	25,268	60,320	3,836
66	979	41,291	46,004	110,601	6,920
67	5,996	33,622	28,661	63,234	4,789
68	501	101,741	46,454	98,372	53,557
69	654	132,625	60,556	133,484	72,672
70	137	27,772	15,507	32,214	22,178
71	726	21,897	17,004	19,982	18,385
72	56,483	146,862	48,452	92,099	10,718
73	17,176	28,956	26,352	50,825	9,491
74	20,343	34,291	31,206	98,093	18,317
75	24,451	277,570	1,775	51,074	23,095
76	70,750	44,838	32,579	116,332	57,176
77	26,645	71,090	21,517	102,177	11,529
78	26,278	70,109	21,220	95,223	10,743
79	35,483	94,675	28,657	149,042	16,817
80	4,627	12,343	3,735	14,731	1,661
81	26,173	69,834	21,137	100,956	11,391
82	8,462	287,935	13,436	120,626	33,198
83	2,982	43,678	26,526	75,881	14,528
84	5,317	77,840	47,274	135,236	25,892
Total	1,939,956	7,503,891	2,600,800	7,441,034	2,401,350

ammoniated phosphates, normal superphosphate, triple superphosphate, and all other phosphate materials.

Estimated 1985 agricultural fertilizer demand is calculated on a state by state basis. Time series regression techniques are applied to annual fertilizer primary nutrient consumption data published by the USDA [39] by fitting four equations to 1963-1980 data. These equations are:

$$Y_t = \alpha + \beta \cdot t$$
$$Y_t = \alpha \cdot t^{\beta}$$
$$Y_t = \alpha + \beta \cdot t + \gamma \cdot t^2$$
$$Y_t = e^{(-(\alpha + \beta \cdot t + \gamma \cdot t^2))}$$

where

t = the year

Y_t = the quantity of a primary nutrient consumed through a given type of fertilizer

α, β, and γ are regression coefficients

Several criteria are used to determine which model best estimates future demand for a given type of fertilizer. These criteria are the significance of the regression coefficients, the degree of auto-correlation, and how well the estimated future demand agrees with industry expectations. No single factor determines which model to use, rather the quality of all the criteria as a whole.

After estimated 1985 fertilizer demands are chosen, each nitrogen fertilizer material's relative share of aggregate nitrogen primary nutrient demand is calculated (12). Likewise, each phosphate material's relative share of aggregate phosphate primary nutrient demand is calculated (13).

$$RN_i = N_i \div \sum_{i=1}^{5} N_i, \text{ for } i = 1 \text{ to } 5 \tag{12}$$

$$RP_j = P_j \div \sum_{j=1}^{4} P_j, \text{ for } j = 1 \text{ to } 4 \tag{13}$$

where

RN_i = Nitrogen fertilizer material i's relative share of aggregate nitrogen demand.

RP_j = Phosphate fertilizer material j's relative share of aggregate phosphate demand.

N_i = Nitrogen primary nutrient content of estimated 1985 demand for nitrogen fertilizer material i.

P_j = Phosphate primary nutrient content of estimated 1985 demand for phosphate fertilizer material j.

Since mixed fertilizers are manufactured from fertilizer materials, the primary nutrients consumed in manufacturing mixed fertilizers must be estimated. Very little quantitative data are available in this area, but discussions with individuals associated with the publication of annual USDA fertilizer consumption data reveal that, a considerable quantity of the fertilizer reported as fertilizer materials is actually used in the manufacture of mixed fertilizers. Thus, it is assumed that the relative shares of fertilizer materials consumed (12 and 13) also represent the relative shares of materials used in the manufacture of mixed fertilizers.

Multipling these relative shares times the estimated 1985 mixed fertilizer primary nutrient demand gives the estimated 1985 amount of each fertilizer material used in the manufacture of mixed fertilizers (14 and 15).

$$MN_i = MN' \cdot RN_i, \text{ for } i = 1 \text{ to } 5 \tag{14}$$

$$MP_j = MP' \cdot RP_j, \text{ for } j = 1 \text{ to } 4 \tag{15}$$

where

MN_i = Nitrogen primary nutrient content of product i used to meet estimated 1985 mixed fertilizer nitrogen primary nutrient demand.

MP_j = Phosphate primary nutrient content of product j used to meet estimated 1985 mixed phosphate primary nutrient demand.

MN'_i = Estimated 1985 mixed fertilizer nitrogen primary nutrient demand.

MP'_j = Estimated 1985 mixed fertilizer phosphate primary nutrient demand.

Total estimated 1985 primary nutrient demand is the aggregate of nutrients consumed as mixtures and materials (16 and 17).

$$TN_i = N_i + MN_i, \text{ for } i = 1 \text{ to } 5 \tag{16}$$

$$TP_j = P_j + MP_j, \text{ for } j = 1 \text{ to } 4 \tag{17}$$

where

TN_i = Total nitrogen primary nutrient demand for nitrogen material i

TP_j = Total phosphate primary nutrient demand for phosphate material j

Each state's estimated 1985 primary nutrient demand by product (16 and 17) is subdivided into estimated primary nutrient demand by crop reporting district (CRD) (18 and 19). If available, individual state fertilizer consumption data are used to estimate each CRD's relative share of total state nitrogen and phosphate consumption for a given state. These relative shares are calculated as a five year average from 1973-1977. In the absence of individual state data, CRD relative shares are estimated from fertilizer consumption data published in the USDA's 1974 Census of Agriculture [42]. This census is based on only 1974 data, however analysis indicates CRD relative shares calculated from USDA data compare very favorably with those based on five years of individual state fertilizer consumption data.

$$CRDN_{ci} = TN_i \cdot RCRDN_c, \text{ for } i = 1 \text{ to } 5 \tag{18}$$

$$CRDP_{cj} = TP_j \cdot RCRDP_c, \text{ for } j = 1 \text{ to } 4 \tag{19}$$

where

$CRDN_{ci}$ = Estimated 1985 nitrogen primary nutrient demand for nitrogen material i in CRD c.

$CRDP_{cj}$ = Estimated 1985 phosphate primary nutrient demand for phosphate material j in CRD c.

$RCRDN_c$ = CRD c's estimated relative share of total state nitrogen primary nutrient demand.

$RCRDP_c$ = CRD c's estimated relative share of total state phosphate primary nutrient demand.

Eventually, the model will require as input the actual number of tons (i.e., primary nutrients plus inert materials) of each type of fertilizer material transported. Thus, primary nutrient demands must be converted to fertilizer material demands by dividing by the appropriate nutrient analysis (20 and 21).

$$MCRDN_{ci} = CRDN_{ci} \div AN_i, \text{ for } i = 1 \text{ to } 5 \tag{20}$$

$$MCRDP_{cj} = CRDP_{cj} \div AP_j, \text{ for } j = 1 \text{ to } 4 \tag{21}$$

where

$MCRDN_{ci}$ = Material demand for fertilizer i in CRD c.

$MCRDP_{cj}$ = Material demand for fertilizer j in CRD c.

AN_i = Nitrogen analysis percentage for fertilizer i.

AP_j = Phosphate analysis percentage for fertilizer j.

Finally, CRD fertilizer demands are aggregated when necessary to conform to the demand regions delineated in Map 1. As stated earlier, these demands are presented in Table 4.

Estimated 1990 Agricultural Fertilizer Demand

The same data and procedure used to estimate 1985 agricultural fertilizer demand are used to estimate 1990 fertilizer demand. The only modification is that state primary nutrient demands for each product (N_i and P_j) are estimated for 1990 rather than 1985 for use in equations (12) and (13). The remainder of the procedure remains exactly the same if the text is modified by substituting "1990" for "1985". Table 5 presents estimated 1990 agricultural fertilizer demand.

Estimated 1985 Nonagricultural Fertilizer Demand

In addition to their basic use as agricultural fertilizer materials, urea and ammonium nitrate are used as inputs to several nonagricultural industries. Urea is used in the manufacture of plastics and livestock feed additives, while ammonium nitrate is used in explosives manufacturing. Nonagricultural fertilizer demand during 1985 is estimated by this study to be 875,771 tons for urea and 1,729,936 tons for ammonium nitrate based on United States International Trade Commission [45] and United States Department of Commerce [40] data, respectively. These estimates are linear trends of urea data from 1971-1978 and ammonium nitrate data from 1960-1978.

Nonagricultural fertilizer demand must be allocated to individual supply points, but before doing so a few adjustments must be made to the fertilizer supply data. For example, it is known that certain production facilities manufacture urea solely for nonagricultural uses [45]. These supply points are removed from the model and total estimated 1985 nonagricultural urea demand is reduced accordingly to 515,771 tons. Calculations are performed on the remaining urea and ammonium nitrate supply points to determine the residual amount of urea and ammonium nitrate remaining at each supply point if maximum nitrogen solutions

Table 5

Estimated 1990 Nitrogen and Phosphate Fertilizer Material Demand

Demand Region	Ammonium Nitrate	Nitrogen Solutions	Urea	Ammonium Phosphates	Triple Superphosphate
1	78,077	109,126	39,217	61,854	79,133
2	101,186	173,448	43,367	65,724	72,441
3	13,238	19,491	59,800	31,428	28,749
4	33,723	46,131	133,746	43,752	45,954
5	16,979	22,244	179,711	17,886	11,067
6	5,430	8,934	32,736	2,800	18,052
7	8,786	19,144	70,640	55,465	11,981
8	13,504	196,678	30,037	127,593	28,729
9	138,848	396,660	26,156	74,886	24
10	32,967	408,778	2,026	120,419	34,167
11	33,191	411,575	2,037	121,245	34,400
12	5,403	116,447	32,135	129,853	27,217
13	4,579	111,762	37,532	140,843	24,737
14	3,916	137,172	53,978	174,278	25,084
15	4,761	102,638	28,324	135,772	28,457
16	6,090	131,213	36,209	154,232	32,326
17	5,794	124,856	34,454	176,286	36,948
18	4,060	87,503	24,146	148,318	31,087
19	3,197	68,897	19,011	114,610	24,022
20	132	177,513	11,687	136,279	51,035
21	108	144,044	9,483	124,629	46,672
22	107	145,528	9,583	116,157	43,498
23	57	136,713	44,674	125,110	51,300
24	55,508	128,457	32,241	136,591	51,168
25	35,970	68,481	19,926	120,687	45,211
26	403	78,291	42,891	143,948	11,237
27	487	94,166	51,587	168,112	13,124
28	334	83,397	65,390	199,668	9,456

Table 5--Continued

Demand Region	Ammonium Nitrate	Nitrogen Solutions	Urea	Ammonium Phosphate	Triple Superphosphate
29	478	92,841	50,863	147,159	11,487
30	475	92,178	50,498	155,457	12,135
31	340	65,988	36,150	115,366	9,007
32	34,567	95,122	56,683	95,958	47,978
33	158	30,600	16,763	44,670	3,487
34	6,319	43,559	12,048	24,122	1,077
35	12,215	84,191	23,287	82,570	3,681
36	11,176	77,047	21,310	91,564	4,083
37	11,024	75,988	21,017	39,430	1,759
38	10,063	69,378	19,189	82,103	3,661
39	18,492	60,898	27,504	101,693	36,221
40	47,128	43,731	36,534	103,348	38,880
41	33,517	66,522	37,785	90,963	36,244
42	14,761	34,311	20,713	66,564	24,925
43	21,682	39,244	57,552	10,054	108,251
44	569	44,976	35,585	92,428	4,537
45	1,006	20,657	16,726	35,246	13,644
46	7,238	148,572	120,309	253,515	98,122
47	30	34,731	50,443	139,874	1,143
48	27	32,056	46,557	129,097	1,054
49	27	30,931	44,924	124,569	1,017
50	564	44,172	51,552	123,351	1,552
51	33	41,000	59,548	165,119	1,348
52	25,952	42,018	57,130	19,212	25,859
53	66,672	92,994	59,824	95,594	117,269
54	36,140	50,409	32,430	55,565	68,163
55	2,215	63,176	12,805	81,413	3,475
56	2,764	79,319	18,887	99,411	4,258
57	3,185	89,341	10,074	67,924	2,876

Table 5--Continued

Demand Region	Ammonium Nitrate	Nitrogen Solutions	Urea	Ammonium Phosphate	Triple Superphosphate
58	5,818	163,275	18,413	91,886	3,889
59	4,815	135,116	15,235	85,877	3,637
60	3,934	110,363	12,446	54,340	2,300
61	96	115,453	100,983	37,976	67,880
62	2,126	101,319	25,793	0	1,585
63	13,371	185,544	2,208	79,203	34,148
64	25,743	357,297	4,257	113,426	48,903
65	66	28,542	32,136	53,616	2,687
66	18	50,697	58,563	99,029	4,980
67	779	40,635	36,070	51,438	2,504
68	33	117,678	54,283	103,285	44,370
69	42	153,400	70,761	140,148	60,206
70	6	31,135	17,152	31,483	18,583
71	131	23,272	17,824	16,807	15,215
72	20,499	184897	56,658	89,659	13,498
73	3,668	31,985	31,404	47,266	9,397
74	4,349	37,877	37,192	91,228	18,139
75	10,551	300,487	1,748	40,319	17,290
76	43,147	49,878	41,502	134,510	50,671
77	9,964	90,013	25,094	99,694	14,778
78	9,827	88,772	24,748	92,909	13,774
79	13,272	119,878	33,420	145,419	21,557
80	1,731	15,631	4,359	14,372	2,130
81	9,788	88,422	24,650	98,503	14,602
82	1,753	301,259	15,271	134,718	17,945
83	668	51,457	33,193	84,615	4,158
84	1,194	91,706	59,152	150,800	7,411
Total	1,163,041	8,601,225	3,131,929	8,084,290	2,120,676

production capacity is utilized.[3] Nonagricultural fertilizer demand is allocated proportionally to only those supply points which have a positive residual, thus insuring that maximum nitrogen solutions manufacture is possible at all supply points. For example, if aggregate residual urea supply is 1,000 tons and a given supply point has a urea residual of 100 tons, that supply point is required to satisfy 10% of total nonagricultural urea demand. Since these adjustments are performed endogenous to the model, Table 1 gives fertilizer supplies before nonagricultural demand has been removed.

Estimated 1990 Nonagricultural Fertilizer Demand

Nonagricultural urea and ammonium nitrate demand for 1990 is estimated to be 880,564 tons and 2,018,544 tons, respectively. The same data and methodology are used in these estimates as are used to estimate 1985 nonagricultural fertilizer demand. One simply substitutes "1990" for "1985" in the text for estimating 1985 nonagricultural demand.

Estimated 1985 and 1990 Fertilizer Storage and Unloading Facilities

The location of 1980 dry warehouse and liquid tank terminal

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[3] Note: those ports importing nitrogen solutions do not require any adjustments to their urea or ammonium nitrate supplies, since the raw material inputs used to manufacture those nitrogen solutions were consumed outside the United States.

fertilizer storage and unloading facilities on the inland waterway system are identified and cross checked through four data sources; three published sources [13; 4; and 15], and one unpublished source [30]. Often these different sources agree quite well, but occasionally discrepancies arise as to what type of fertilizer facilities, if any, exist at a particular location. In these situations, two industry contacts are consulted to resolve any problems.

Industry sources have also provided 1980 storage capacity data for most storage locations. In the absence of these data, it is assumed for locations where warehouses are known to exist, that 30,000 tons of storage are available. For locations with no known storage, but maintaining fertilizer unloading facilities, it is assumed that only 10,000 tons of temporary storage are available.

Industry sources also believe that very little additional river storage capacity is planned to be built between 1980 and 1990. Thus, the estimated 1985 and 1990 river storage capacities presented in Table 6 are actually 1980 capacities. Storage is aggregated by type of fertilizer (dry or liquid) approximately every 100 miles along the inland waterway system to simplify the model. Finally, it is assumed that each river warehouse has an annual throughput capacity equal to three times its annual storage capacity. Likewise, each river tank terminal's throughput capacity is equal to two and one-half times its annual storage capacity.

Fertilizer pipeline tank terminal locations and storage capacities are identified from unpublished industry data and are presented in Table 7. For locations whose storage capacities are missing, it is assumed that

Table 6

Estimated Tons of Storage Available at River Warehouse and Tank Terminal Locations during 1985 and 1990

Location	Dry Storage	Liquid Storage
Friars Point, Mississippi	51,000	28,000
Barfield, Arkansas	20,000	28,000
Birds Point, Missouri	--	20,000
Chester, Illinois	10,000	--
Herculaneum, Missouri	--	20,000
Granite City, Illinois	215,000	74,000
Palmyra, Missouri	10,000	20,000
Burlington, Iowa	86,000	52,000
Clinton, Iowa	80,000	93,000
Prairie du Chien, Wisconsin	80,000	95,000
Pine Bend, Minnesota	270,000	30,000
Catoosa, Oklahoma	30,000	--
South Point, Ohio	--	20,000
Cincinnati, Ohio	90,000	98,000
Owensboro, Kentucky	30,000	35,000
Louisville, Kentucky	10,000	20,000
Boonville, Missouri	50,000	21,000
Kansas City, Kansas	90,000	28,000
Mound City, Missouri	10,000	--
Nebraska City, Nebraska	--	30,000
Council Bluffs, Iowa	53,000	--
Sioux City, Iowa	130,000	40,000
Meredosia, Illinois	--	52,000
Pekin, Illinois	200,000	186,000
Joliet, Illinois	142,000	124,500
Calumet City, Illinois	40,000	--

Table 7

Estimated Tons of Storage Available at Pipeline Tank Terminal Locations during 1985 and 1990

Location	Liquid Storage
Grand Forks, North Dakota	15,000
Fargo, North Dakota	10,000
Alexandria, Minnesota	12,500
Watertown, South Dakota	10,000
Sioux Falls, South Dakota	10,000
Mason City, Iowa	15,000
Des Moines, Iowa	14,000
Blair, Nebraska	15,000
Omaha, Nebraska	9,000
Doniphan, Nebraska	20,000
Falls City, Nebraska	27,000
Amboy (Eldena), Illinois	34,000
Valmeyer, Illinois	9,000
Breese, Illinois	6,000
Jordan, Indiana	10,000
Greenwood, Indiana	11,000
Dublin, Indiana	131,000
Newton, Indiana	15,000

15,000 tons of storage exist. Also, as with river tank terminals, maximum annual throughput capacities for tank terminal locations are assumed to be equal to two and one-half times each locations annual storage capacity.

Estimated 1980 Transportation and Handling Costs

The set of transportation and handling costs used in both the 1985 and 1990 models, represents the relationships that existed on March 1, 1980. Since no unusual events were influencing the fertilizer transportation industry at this time, a set of transportation and handling costs chosen from this year are used to represent future cost relationships of the fertilizer industry. March first is chosen as the specific point during 1980 for which fertilizer transportation costs are collected because during March, April, and May approximately 40% of all fertilizer is shipped to retail fertilizer dealers [25].

Table 8 presents the transportation and handling cost of shipping ammoniated phosphates and urea from Donaldsonville, Louisiana to Nevada, Iowa by various modes. Different costs are incurred by each mode due to many factors, some of which are: distance travelled, fuel efficiency, and payload capacity of the equipment.

Differences in transportation and handling costs exist within transportation modes also. For example, the estimated cost of shipping ammonium nitrate 231 miles between Birmingham, Alabama and Marks, Mississippi by truck is 1179 cents per ton, while the cost of shipping ammonium nitrate the same distance between Lawrence, Kansas and Penalosa,

Table 8

Estimated Cent per Ton Transportation and Handling Costs of Shipping Fertilizer from Donaldsonville, Louisiana to Nevada, Iowa during 1980

Fertilizer	Mode	Rate
Urea	Rail	2457
Urea	Barge-Rail	1690
Urea	Barge-Truck	1819
Ammoniated Phosphate	Rail	2358
Ammoniated Phosphate	Barge-Rail	1616
Ammoniated Phosphate	Barge-Truck	1819

Kansas is 1258 cents per ton. These differences within transportation modes are due primarily to differences in the cost structure of each mode in different regions of the country. In the case of truck cost, annual license and registration fees vary considerably from state to state, thus introducing a different cost structure to each state. These differences between and within transportation mode cost structures that provide the model with numerous alternatives to optimize the fertilizer transportation industry.

Estimated railroad transportation rates

The phrase "estimated railroad transportation rates" is a misnomer, since the railroad transportation rates used in this model are actual railroad freight rates. Over 23 railroad freight tariffs and numerous supporting documents are used to collect 97.3% of all 2,208 possible supply point-demand region and supply point-supply point rate combinations. Whenever possible, rates are collected for 100 ton covered hopper railroad cars; the most common and most efficient type of railroad equipment in use today. In those few cases where rates can not be located in railroad tariffs, linear regression techniques are used to estimate rates such that rates are a function of mileage travelled. Regressions are developed for each type of fertilizer.

Prior to the passage of the Staggers Railroad Act of 1980, railroad freight rates were permitted to be modified through Interstate Commerce Commission (ICC) Ex Parte rate increases which allow railroads to raise their rates a certain maximum percentage to keep up with rising operating costs. Thus, rates collected from various tariffs are often listed at different Ex Parte levels and must be adjusted to a common level to be useful. Since Ex Parte level 374 was in effect on March 1, 1980, all fertilizer rates are adjusted to this level.

Railroad freight rates for the five fertilizers modelled in this study are predominantly expressed as single-car rates (i.e., cents per ton assuming a minimum shipment of one railroad hopper car). However, a few multiple-car rates exist (e.g., five-car and 25-car), which offer substantial reductions in cent per ton transportation costs. In order for a supply point-demand region combination to use a multiple-car rate, it is assumed that fertilizer is shipped from the supply point as a multiple-car shipment to a warehouse located at the destination of the multiple-car rate, stored and handled at the warehouse, and eventually shipped to the demand region in a single rail car or truck. If the total cost of multiple-car shipping (i.e., multiple-car rate, plus handling at the warehouse, plus shipping to the demand region) is less than the direct single-car rate from the supply point to the demand region, the multiple-car shipping cost is substituted for the single-car rate. Selected railroad rates are presented in Table 9.

Estimated truck rates

Since published fertilizer truck rate data are not available, fertilizer truck costs are estimated for two types of equipment: a

Table 9

Selected Ex Parte 374 Railroad Rates (Cents per Ton)

From	To	Fertilizer	Rate
Cleveland, Ohio	Neville Island, Pennsylvania	Nitrogen Solutions	1173
Verdigris, Oklahoma	McLean, Illinois	Nitrogen Solutions	1968
Beatrice, Nebraska	Osceola, Iowa	Nitrogen Solutions	1536
Woodward, Oklahoma	Amarillo, Texas	Ammonium Nitrate	862
Seargent Bluff, Iowa	Nevada, Iowa	Ammonium Nitrate	820
Donora, Pennsylvania	Gallipolis, Ohio	Ammonium Nitrate	1721
Woodstock, Tennessee	Denison, Iowa	Urea	2149
Donaldsonville, Louisiana	Baltimore, Maryland	Urea	3964
Clinton, Iowa	Britt, Iowa	Urea	770
Bartow, Florida	Carlinville, Illinois	Ammonium Phosphate	2347
Fort Madison, Iowa	Stanwood, Iowa	Ammonium Phosphate	620
White Springs Florida	Charlottesville, Virginia	Ammonium Phosphate	2194
Lee Creek, North Carolina	Macon, Georgia	Triple Superphosphate	1880
Bartow, Florida	Yankton, South Dakota	Triple Superphosphate	3524
Pascagoula, Mississippi	Sylvester, Georgia	Triple Superphosphate	1560

tractor-semitrailer used for dry materials, and a tractor-semitanker used for liquid materials. Total annual costs are estimated in cents per ton for March 1, 1980 (22).

$$TC = FC + VC \cdot M + TR \tag{22}$$

where

TC = Total annual truck cost

FC = Total fixed cost

VC = Variable cost per mile

M = Total miles travelled per year

TR = Transfer cost per year

Components of annual fixed cost are license fees, highway use taxes, overhead expenses, maintenance and repair, and annual ownership expense calculated from the equipment's purchase price (net of tires), salvage value, service life, and the interest rate. Variable cost components include fuel, oil and oil filters, tires, and drivers wages. Finally, the transfer cost is a function of the transfer time (time to load and unload the truck) and the driver's wages. Table 10 presents all the data used in this analysis to estimate truck cost for both types of equipment.

The number of trips and total distance travelled during a year for a given type of equipment is a function of the trip distance, average truck speed, transfer time, and number of working hours per year (23 and 24). Table 11 presents the assumed relationships between truck speed and distance travelled.

Table 10

Truck Cost Data for March 1980

Item	Tractor Semitrailer	Tractor Semitanker
I. Fixed Costs:		
A. Interest and Depreciation:		
1. Interest Rate:	13%	
2. Purchase Price (Net of Tires):	$54,043	$77,873
3. Service Life:	5 years	Tractor: 5 years Tanker: 20 years
4. Salvage Value:	$19,248	Tractor: $15,399 Tanker: $5,071
B. Annual License Fees and Taxes:		
1. State License Fee:	Varies by state (e.g., Iowa: $1,695)	
2. Federal Highway Use Tax:	$228	
C. Annual Insurance Premium:	$3,722	
D. Annual Management Expense:	$480	
E. Annual Maintenance and Repairs:	5% of purchase price	
II. Variable Costs:		
A. Fuel:		
1. Mileage per Gallon:	5.5	
2. Cost per Gallon:	$1.1729	
3. Cost per Mile:	$0.21325	
B. Oil and Oil Filter:		
1. Quantity per Change:	42 quarts plus filter	
2. Cost per Change:	$51.38	
3. Miles per Change:	10,000	
4. Cost per Mile:	$0.00514	
C. Tires:		
1. Total Cost:	$5,277	
2. Service Life:	100,000 miles	
3. Cost per Mile:	$0.05277	
D. Driver's Wage:	Varies by state (e.g., Iowa: $9.55 per hour)	

Table 10--Continued

Truck Cost Data for March 1980

Item	Tractor Semitrailor	Tractor Semitanker
III. Other Data:		
A. Payload Capacity:	55,000 pounds	52,215 pounds
B. Working Hours per Year:	2,200	
C. Transfer Time:	1 hour	0.75 hour

Table 11

Assumed Relationship between Truck Speed and Distance Travelled

Round Trip Distance in Miles	Average Speed in Miles per Hour
30	35
50	35
100	40
150	40
200	40
250	45
300	45
350	50
400	50

$$N = H \div ((D \div S) + T) \tag{23}$$

$$M = D \cdot N \tag{24}$$

where

N = Number of trips per year

H = Total working hours per year

D = Round trip distance in miles per trip

S = Speed in miles per hour

T = Transfer time in hours per trip

Average truck cost per ton-mile is estimated assuming no other commodity is backhauled (25).

$$AC = TC \div (M \cdot PL) \tag{25}$$

where

AC = Average truck cost in cents per ton-mile

PL = Payload in tons

Truck cost functions are estimated based on the mileages in Table 11 (26).

$$C = \alpha + \beta \cdot m \tag{26}$$

where

C = Truck cost in cents per ton

m = One-way trip mileage

α and β are regression coefficients

Industry sources indicate that a 6% profit margin on fertilizer trucking is reasonable. Thus, estimated truck costs are adjusted to reflect this 6% assumption (27).

$$R = C \div (1 - 0.06) \tag{27}$$

where

R = Estimated truck rate in cents per ton

Estimated barge rates

Published barge rate data are not available for fertilizer. The Merchants Exchange in St. Louis, Missouri recently began trading northbound barge freight; however, no data are available for the time frame of this study. Thus, fertilizer barge rates are estimated from data collected from barge industry executives. These sources indicate that northbound barge rates are typically quoted as about 50% of the southbound grain barge rate to southern Louisiana. Thus, barge rates for fertilizer moving north from southern Louisiana to river warehouses and tank terminals are estimated by multipling southbound grain rates times 0.5. Also, northbound barge rates for fertilizer shipped from central Florida are estimated as fertilizer barge rates north from southern Louisiana plus the following per ton charges:

$2.73 truck rate from central Florida to Tampa, Florida

$5.465 Tampa barge loading fee

$7.50 fee for shipping from Tampa to southern Louisiana and reloading to river barges in southern Louisiana

Total additional barge expense of shipping fertilizer from central Florida to southern Louisiana is $15.695 per ton. Table 12 presents estimated fertilizer barge rates from New Orleans, Louisiana and central Florida to warehouse and tank terminal locations along the inland waterway system.

Barge rates are always used in combination with railroad or truck rates so that fertilizer can be shipped from a production facility through a river warehouse or tank terminal to a demand region. The total estimated cost of such a barge combination movement equals the estimated barge rate, plus the estimated rail or truck rate, plus the estimated handling cost at the river warehouse or tank terminal. Handling costs at river warehouses and tank terminals are estimated from a study conducted at Iowa State University [2]. This study estimated the variable handling costs at a fertilizer warehouse to be $1.44 per ton. The primary component of this cost was labor. Thus, 1980 fertilizer warehouse and tank terminal handling costs are estimated by inflating the 1974 variable handling cost estimate by the wage rate of non-farm employees in the private sector [43]. This technique yields a variable handling cost estimate of $2.23 per ton for March 1980.

Estimated pipeline rates

As in the case of railroad rates, the term "estimated" is a misnomer when used in reference to fertilizer pipeline rates. All pipeline rates are collected from actual tariffs which were effective March 1, 1980.

Table 12

Estimated 1980 Barge Rates (Cents per Ton)

River Warehouse or Tank Terminal Location	From New Orleans	From Tampa
Friars Point, Mississippi	299	1869
Barfield, Arkansas	351	1921
Birds Point, Missouri	410	1980
Chester, Illinois	431	2001
Herculaneum, Missouri	431	2001
Granite City, Illinois	431	2001
Palmyra, Missouri	557	2127
Burlington, Iowa	584	2154
Clinton, Iowa	612	2182
Prairie du Chien, Wisconsin	690	2260
Pine Bend, Minnesota	774	2344
Catoosa, Oklahoma	592	2162
South Point, Ohio	509	2079
Cincinnati, Ohio	469	2039
Owensboro, Kentucky	404	1974
Louisville, Kentucky	446	2016
Boonville, Missouri	810	2380
Kansas City, Kansas	810	2380
Mound City, Missouri	955	2525
Nebraska City, Nebraska	955	2525
Council Bluffs, Iowa	955	2525
Sioux City, Iowa	1110	2680
Meredosia, Illinois	534	2104
Pekin, Illinois	553	2123
Joliet, Illinois	603	2173
Calumet City, Illinois	665	2235

These rates are quoted from three fertilizer injection points to various pipeline tank terminals as given in Table 13. Notice that rates are not quoted from all injection points to all tank terminals. This is due primarily to the geographical structure of the pipeline which makes it either physically or economically impossible to ship fertilizer between certain pairs of points.

Pipeline rates, as in the case of barge rates, are always used in combination with railroad or truck rates. Thus, the total estimated cost of a pipeline combination shipment equals the estimated pipeline rate, plus the estimated rail or truck rate, plus the estimated handling cost at the pipeline tank terminal. Handling costs at pipeline tank terminals are estimated as the actual fee charged by the pipeline carrier to load fertilizer into trucks or railroad cars at the terminal. This fee was 87 cents per ton during March 1980.

Waterway User Charges

This study examines the impact of four waterway user charge scenarios on both the 1985 and 1990 fertilizer models. These user charges fall into two categories: fuel taxes and segment taxes. A fuel tax is simply a tax levied on each gallon of fuel consumed on the inland waterway system, analogous to the federal highway fuel tax added to all fuel consumed by automobiles and trucks, on the other hand, a segment tax is similar to the tolls collected by the feudal lords of medieval Europe. Anyone desiring safe passage on the river past a lord's castle was

Table 13

Estimated 1980 Pipeline Rates (Cents per Ton)

Destinations	Origins Sioux City, Iowa	 Lawrence, Kansas	 Verdigris, Oklahoma
Grand Forks, North Dakota	788	1080	1500
Fargo, North Dakota	710	973	--
Alexandria, Minnesota	--	--	1318
Watertown, South Dakota	444	858	--
Sioux Falls, South Dakota	--	601	1020
Mason City, Iowa	--	586	1004
Des Moines, Iowa	--	427	847
Blair, Nebraska	--	442	862
Omaha, Nebraska	--	427	--
Doniphan, Nebraska	--	507	925
Falls City, Nebraska	--	244	664
Amboy (Eldena), Illinois	--	727	--
Valmeyer, Illinois	--	--	576
Breese, Illinois	--	--	1105
Jordan, Indiana	--	--	1975
Greenwood, Indiana	--	--	1817
Dublin, Indiana	--	--	1263
Newton, Indiana	--	--	1540

required to pay a toll or face the consequences of being blown out of the water. Hopefully, the penalty imposed by the United States government is less harsh, however the concept of a segment tax remains the same. Anyone shipping freight on the inland waterway system is assessed a ton-mile tax unique to each river. Failure to pay the tax could be grounds for denying passage through the inland waterway system's locks and dams.

The level of waterway user charge taxes used in this analysis has been provided by the United States Depatrment of Transportation from a study conducted by Data Resources, Inc. (DRI) [12]. To estimate 1985 user charges, DRI first developed cost and barge traffic data for 1985. Using existing macro-economic models, DRI projected 1985 barge traffic for each segment of the inland waterway system. Also, the Army Corps of Engineers supplied data on the cost of operation, maintenance, repair, and new construction (OMRC) of each river segment in 1979 constant dollars. The cost of new construction was amortized over 50 years using a constant dollar interest rate of 3%. This constant dollar interest rate is equivalent to a current dollar interest rate of 13-15% assuming the present rate of inflation. Given these cost and traffic data for 1985, DRI converted the total amount of money to be recovered into a per gallon fuel tax or a ton-mile segment tax depending on the type of tax being modelled. These taxes are added to the original barge rates of the no user charge scenario. Introduction of these higher rates causes some barge traffic to divert to other modes, leaving less traffic on the waterways. This traffic will no longer yield the required amount of cost recovery, so it is necessary to increase the user charge. The new, higher charge is applied again to the remaining traffic. This iteration process is repeated four times. By the fourth iteration, the barge traffic level usually stabilizes. The only time it does not is in the case of a high-cost river segment whose traffic can not support its costs. In these cases, it is obvious by the fourth iteration that all the traffic is disappearing.

The same iterative technique is used to estimate 1990 user charges. The only difference is that 1990 data on commercial navigation costs and traffic data are used to estimate waterway user charges.

Each waterway user charge scenario is implemented by modifying the basic set of fertilizer barge rates presented earlier to reflect the user charge. Some scenarios also adjust railroad freight rates to reflect how the railroad industry might respond to a given waterway user charge. Railroad response diverts some fertilizer traffic back to the barge mode. An increase in barge traffic means a lower user charge level can be used to recover all OMRC costs. However, the amount of traffic diverted is anticipated to be relatively small compared to total fertilizer barge traffic. Thus, the user charge level required to recover all OMRC costs will change very little. Therefore, this study assumes no change in waterway user charge levels for railroad response scenarios. A detailed discussion of each user charge scenario follows.

Fuel tax (1985)

It is estimated that a 32.4¢ per gallon fuel tax is necessary to recover 100% of all 1985 operation, maintenance, repair, and construction costs of the inland waterway system [12]. However, construction and operation costs of locks and dam 26 are not considered assessable until after 1985. The 32.4¢ per gallon fuel tax is converted to a cent per ton tax unique to each river warehouse and tank terminal through a procedure developed at Iowa State University [1]. This procedure first converts the cent per gallon tax to a cent per ton-mile tax knowing the fuel efficiency and payload of a typical barge tow. Then the cent per ton-mile tax is converted to a cent per ton tax knowing the distance each river warehouse and tank terminal is from Baton Rouge, Louisiana, the start of the taxable inland waterway system. This procedure also assumes that all dry fertilizer shipments are backhauled in the same barges used for hauling grain south to New Orleans, Louisiana. Since these barges return north to pickup more grain regardless of whether or not any fertilizer is being backhauled, only the additional fuel consumed in shipping a loaded versus empty barge back north from New Orleans is allocated to fertilizer and taxed accordingly. This additional fuel consumption, approximately 21% of an empty northbound barge movement, is converted to a cent per ton user charge as described above for each river warehouse location and added to the appropriate dry fertilizer barge rate. Shipments of liquid fertilizer however, are not considered to be backhaul movements and are taxed on the amount of fuel consumed for a complete trip. The 32.4¢ per gallon fuel tax converted to a cent per ton tax for both dry and liquid fertilizer shipped from New Orleans is presented in Table 14.

Table 14

Estimated 1985 Cent per Ton Taxes Necessary to Recover 100% OMRC from New Orleans to River Destinations under a 32.4 ¢ per Gallon Fuel Tax

River Destination	Tax for Dry Fertilizers	Tax for Liquid Fertilizers
Friars Point, Mississippi	4.2	35.3
Barfield, Arkansas	5.9	48.7
Birds Point, Missouri	7.3	60.8
Chester, Illinois	8.4	70.0
Herculaneum, Missouri	8.9	73.8
Granite City, Illinois	9.3	82.0
Palmyra, Missouri	10.7	97.4
Burlington, Iowa	11.6	107.1
Clinton, Iowa	12.7	119.9
Prairie du Chien, Wisconsin	14.0	133.3
Pine Bend, Minnesota	16.0	154.9
Catoosa, Oklahoma	13.5	142.1
South Point, Ohio	11.2	110.4
Cincinnati, Ohio	10.3	98.4
Owensboro, Kentucky	8.6	77.7
Louisville, Kentucky	9.5	89.1
Boonville, Missouri	14.1	123.9
Kansas City, Kansas	18.3	159.4
Mound City, Missouri	22.0	197.2
Nebraska City, Nebraska	23.6	213.8
Council Bluffs, Iowa	25.0	228.2
Sioux City, Iowa	28.2	260.8
Meredosia, Illinois	10.3	93.7
Pekin, Illinois	11.2	103.5
Joliet, Illinois	12.6	118.7
Calumet City, Illinois	13.0	122.8

100% OMRC recovery segment tax (1985)

Estimated cent per ton-mile segment taxes necessary to recover 100% of all OMRC costs of the inland waterway system during 1985 are presented in Table 15 [12]. These taxes vary by river depending on the number and condition of the locks and dams, dredging requirements, and future construction plans of the United States Army Corps of Engineers. However, construction and operation costs of locks and dam 26 are not considered assessable until after 1985.

Cent per ton-mile taxes are converted to cent per ton taxes which are added to the appropriate fertilizer barge rates for each fertilizer warehouse and tank terminal. No distinction is required between dry and liquid fertilizer as in the fuel tax scenario. Table 16 presents the 100% OMRC segment tax in cents per ton for fertilizer shipped from New Orleans, Louisiana.

100% OMRC recovery segment tax (1985), 50% railroad response

This user charge scenario assumes that railroads will respond to a 100% OMRC segment tax by raising railroad rates an amount equal to one-half the tax. Only those railroad rates which originate in either central Florida or southern Louisiana and compete directly with a barge combination mode alternative are increased. The amount of increase for a given supply point-demand region pair is equal to one-half the tax

Table 15

Estimated 1985 and 1990 Cent per Ton-Mile Segment Taxes Necessary to Recover 100% OMRC Costs

River Segment[a]	1985	1990
Upper Mississippi	\$0.25	\$0.23
Middle Mississippi	0.10	0.23
Lower Mississippi	0.07	0.05
Arkansas	1.31	0.62
Ohio	0.05	0.03
Missouri	0.32	0.31
Illinois	0.18	0.17

[a] Mississippi river segments are defined relative to the following towns and river mileages.

Upper--One-tenth mile north of McGregor, Iowa (635.1) to Minneapolis, Minnesota (857.0).
Middle--Junction of Mississippi (0.0) and Ohio Rivers to McGregor, Iowa (635.0).
Lower--One mile north of Baton Rouge, Louisiana (255.1) to junction of Mississippi (953.8) and Ohio Rivers.

Table 16

Estimated 1985 Cent per Ton Taxes Necessary to Recover 100% OMRC from New Orleans to River Destinations under a Segment Tax

River Destination	Tax for Dry or Liquid Fertilizers
Friars Point, Mississippi	29.4
Barfield, Arkansas	40.5
Birds Point, Missouri	50.7
Chester, Illinois	61.3
Herculaneum, Missouri	65.9
Granite City, Illinois	69.1
Palmyra, Missouri	98.0
Burlington, Iowa	119.2
Clinton, Iowa	147.2
Prairie du Chien, Wisconsin	176.5
Pine Bend, Minnesota	223.8
Catoosa, Oklahoma	625.1
South Point, Ohio	83.7
Cincinnati, Ohio	75.6
Owensboro, Kentucky	61.8
Louisville, Kentucky	69.4
Boonville, Missouri	132.9
Kansas City, Kansas	196.8
Mound City, Missouri	231.0
Nebraska City, Nebraska	250.1
Council Bluffs, Iowa	266.7
Sioux City, Iowa	304.0
Meredosia, Illinois	84.8
Pekin, Illinois	100.1
Joliet, Illinois	123.8
Calumet City, Illinois	130.3

associated with the cheapest barge combination rate between the given supply point-demand region pair.

100% OMRC recovery segment tax (1985), 100% railroad response

This user charge scenario is very similar to the immediately preceding 50% railroad response scenario. The only difference is that the amount of railroad response for a given supply point-demand region pair is equal to the tax associated with the cheapest barge combination shipment between the given supply point and demand region.

Fuel tax (1990)

It is estimated that a 38.1¢ per gallon fuel tax is necessary to recover 100% of all 1990 OMRC costs of the inland waterway system [12]. Construction and operation cost of locks and dam 26 are included in these 1990 OMRC cost estimates. The cent per gallon fuel tax is converted to a cent per ton tax using the same procedure and assumptions as the 32.4¢ per gallon fuel tax (1985) scenario. Table 17 presents the 38.1¢ per gallon fuel tax converted to a cent per ton tax for both dry and liquid fertilizer shipped from New Orleans.

100% OMRC recovery segment tax (1990)

Estimated cent per ton-mile segment taxes necessary to recover 100%

Table 17

Estimated 1990 Cent per Ton Taxes Necessary to Recover 100% OMRC from New Orleans to River Destinations under a 38.1 ¢ per Gallon Fuel Tax

River Destination	Tax for Dry Fertilizers	Tax for Liquid Fertilizers
Friars Point, Mississippi	5.0	41.6
Barfield, Arkansas	6.9	57.3
Birds Point, Missouri	8.6	71.5
Chester, Illinois	9.9	82.3
Herculaneum, Missouri	10.4	86.8
Granite City, Illinois	10.9	96.5
Palmyra, Missouri	12.6	114.6
Burlington, Iowa	13.6	126.0
Clinton, Iowa	15.0	141.0
Prairie du Chien, Wisconsin	16.4	156.8
Pine Bend, Minnesota	18.8	182.2
Catoosa, Oklahoma	15.9	167.1
South Point, Ohio	13.2	129.8
Cincinnati, Ohio	12.1	115.7
Owensboro, Kentucky	10.2	91.3
Louisville, Kentucky	11.2	104.8
Boonville, Missouri	16.6	145.7
Kansas City, Kansas	21.5	187.5
Mound City, Missouri	25.8	231.8
Nebraska City, Nebraska	27.7	251.4
Council Bluffs, Iowa	29.4	268.4
Sioux City, Iowa	33.1	306.7
Meredosia, Illinois	12.1	110.2
Pekin, Illinois	13.2	121.7
Joliet, Illinois	14.8	139.5
Calumet City, Illinois	15.2	144.4

of all OMRC costs of the inland waterway system during 1990 are presented in Table 15 [12]. For most river segments, 1985 and 1990 ton-mile segment tax levels are very similar. However, construction and operation costs of new lock and dam 26 more than double the segment tax for the middle Mississippi River between 1985 and 1990. On the Arkansas River, an increase in nonagricultural commodity shipments, such as coal, reduces the segment tax for the Arkansas River by half between 1985 and 1990. Table 18 presents the 100% OMRC segment tax in cents per ton for fertilizer shipped from New Orleans.

<u>100% OMRC recovery segment tax (1990), 50% railroad response</u>

This user charge scenario functions exactly the same as the 1985 50% railroad response user charge, except the response is with respect to the 1990 segment tax.

<u>100% OMRC recovery segment tax (1990), 100% railroad response</u>

This user charge scenario functions exactly the same as the 1985 100% railroad response user charge, except the response is with respect to the 1990 segment tax.

Table 18

Estimated 1990 Cent per Ton Taxes Necessary to Recover 100% OMRC from New Orleans to River Destinations under a Segment Tax

River Destination	Tax for Dry or Liquid Fertilizers
Friars Point, Mississippi	21.0
Barfield, Arkansas	28.9
Birds Point, Missouri	36.6
Chester, Illinois	60.9
Herculaneum, Missouri	71.4
Granite City, Illinois	78.8
Palmyra, Missouri	109.8
Burlington, Iowa	129.3
Clinton, Iowa	155.1
Prairie du Chien, Wisconsin	182.1
Pine Bend, Minnesota	225.6
Catoosa, Oklahoma	302.0
South Point, Ohio	56.0
Cincinnati, Ohio	51.1
Owensboro, Kentucky	42.8
Louisville, Kentucky	47.4
Boonville, Missouri	141.9
Kansas City, Kansas	203.8
Mound City, Missouri	236.9
Nebraska City, Nebraska	255.4
Council Bluffs, Iowa	271.5
Sioux City, Iowa	307.7
Meredosia, Illinois	98.0
Pekin, Illinois	112.4
Joliet, Illinois	134.8
Calumet City, Illinois	141.0

MODEL VALIDATION

The validity or prediction accuracy of this model was tested before using it to project future fertilizer marketing patterns. Historical marketing patterns for 1978 were compared to those projected by the model using the following data:

- o 1978 fertilizer production facility capacities
- o Fertilizer consumption for the fiscal year ending June 30, 1978
- o Ex Parte 349 railroad rates, March 1978 barge and pipeline rates, and estimated March 1978 truck rates.

All other model assumptions such as warehouse and tank terminal capacities remained the same as used in the rest of this study. Historical modal marketing patterns were collected from a transportation survey conducted by The Fertilizer Institute (TFI) of its members [47]. This is the best marketing data available about the industry. Important points to note about the survey are:

- o The survey is based on calendar year 1978
- o Only TFI members were surveyed; about 90% of the industry
- o It is estimated by TFI that 90% of rail, 75% of barge-rail and barge-truck, 70% of pipeline-rail and pipeline-truck, and only 25% of truck movements were surveyed

Since the TFI survey is based on calendar year 1978, it is actually a partial survey of fertilizer marketed for two crop years. The first four or five months of the survey, approximately January through May, account for some of the fertilizer applied to 1978 crops. This in itself is not bad except for the fact that the fertilizer market for the 1978 crop year was seriously depressed due to:

- o low and/or anticipated low commodity prices
- o uncertainty about government programs
- o wet field conditions

while the fertilizer market for the 1979 crop year was very active and optimistic. The aggregation of samples from these two contrasting crop years forces us to question the quantitative strength of the survey. Also, when a copy of the survey was first obtained, several major errors were discovered in the data. The most obvious error was that a very large volume of fertilizer was moving by barge from Alberta, Canada to the midwest even though no water route exists between these regions. The TFI was informed of this error so that they could correct a data coding problem. However, it is known that several other minor errors still remain in the data, suggesting that numerous other unidentified errors might exist in the TFI survey. Thus, it was concluded that no meaningful quantitative comparison could be made between the marketing patterns of the survey and the model.

A better approach is to compare the relative share or percentage of fertilizer shipped by mode. Total tonnage shipped in either the model or the survey has little effect on the relative modal shares. However, the problem with this approach is that the raw survey data underestimates barge and pipeline shipments, and severely underestimates truck movements of fertilizer. Since we do not know the exact degree of error in each case, modal market share calculations are made on only the raw survey data. Table 19 compares modal shares calculated from the survey to modal shares projected by the model for 1978. In most cases, the model and the survey compare quite well. For example, the model overstates barge modal shares by only 0%, 3.7%, and 1.5% for urea, ammoniated phosphates, and triple superphosphate respectively, while understating nitrogen solutions modal shares by only 2.4%.

Finally, since ammonium nitrate production facilities are much more market oriented than other fertilizer production facilities, one would expect most ammonium nitrate to be shipped by truck. This hypothesis is confirmed by the model's results. However, survey results indicate that most ammonium nitrate is shipped by rail. This discrepancy is accounted for by recalling that the survey sampled only about 25% of all truck shipments. Thus, we would expect the survey to severely underestimate ammonium nitrate truck shipments, which it does.

The TFI survey is a great advance in fertilizer transportation research. However, problems with the survey make it impossible to quantitatively compare it to the model to determine the model's validity. Even so, valuable qualitative comparisons can be made which indicate that the model functions quite well.

Table 19

A Comparison of Historical Modal Shares to Modal Shares Projected by the Model for 1978

Fertilizer	Data Base	Rail	Truck	Barge	Pipeline
Urea	Historical	45.4	24.8	29.7	-
	Model	32.9	37.4	29.7	-
Ammoniated Phosphates	Hostorical	53.0	10.7	36.3	-
	Model	45.8	14.2	40.0	-
Triple Superphosphate	Historical	64.5	19.0	16.6	-
	Model	72.5	9.4	18.1	-
Ammonium Nitrate	Historical	63.2	36.8	-	-
	Model	27.2	72.8	-	-
Nitrogen Solutions	Historical	14.3	50.7	27.0	8.0
	Model	19.0	48.1	24.6	8.3

RESULTS

The impact of each waterway user charge scenario is analyzed by comparing the computer solutions of each user charge scenario to the base solution which contains no waterway user charges. Base solutions are generated for both the 1985 and 1990 fertilizer industries.

Each base and user charge solution is summarized in terms of three basic quantities; revenue collected, taxes collected, and quantity of fertilizer shipped, which are reported as follows:

- o Barge, rail, truck, and pipeline modal shares by fertilizer, market, and production facility
- o Fertilizer market patterns by fertilizer, market, production facility, and mode of transport
- o Total cost of fertilizer distribution by fertilizer, market, production facility, and mode of transport
- o Tax collected by type of fertilizer and river
- o Total revenue collected by mode of transport

1985 Base and User Charge Computer Solutions

All user charge solutions generated for 1985 are based on estimated 1985 fertilizer supplies and demands, and estimated 1980 transportation and handling costs. Each user charge scenario modifies the basic 1980 transportation and handling cost structure by increasing barge and/or railroad rates to reflect the desired user charge. The following user charge scenarios are modelled for 1985:

- o 32.4¢ per gallon fuel tax (1985)
- o 100% OMRC recovery segment tax (1985)
- o 100% OMRC recovery segment tax (1985), plus 50% railroad response
- o 100% OMRC recovery segment tax (1985), plus 100% railroad response

Appendix A reports pictorially all fertilizer shipments by mode for the 1985 base scenario which assesses no user charge tax.

The total cost of shipping the five fertilizers modelled in this study under each user charge scenario is presented in Table 20. The base solution cost of $285,652,844 changes very little under any user charge scenario, especially the fuel tax case where only the additional fuel required to ship a loaded rather than empty barge back upstream is assessed the tax. The cost of shipping all fertilizer increases only 0.4% under the fuel tax and 2.1% under the segment tax. This means that the average increase in cost per ton paid for fertilizer shipped by barge is $0.30 and $1.52 per ton under the fuel and segment tax, respectively. The impact of railroad response measured relative to the segment tax is rather small also. The total cost of shipping all fertilizer, relative to the segment tax scenario, increases 0.7% under 50% railroad response and 1.4% under 100% railroad response. As a consequence, the average cost per ton paid for fertilizer shipped by rail rises $0.85 and $1.60 per ton for the 50% and 100% railroad response scenarios, respectively.

Table 20

Estimated Total Fertilizer Transportation and Handling Costs Plus User Charges Collected under Each 1985 User Charge Senario (Millions of Dollars Except Where Noted)

User Charge Solution	Total Cost	Total Change in Cost	Cost Change due to User Charge	Cost Change due to Railroad Response	Average Change in Cost (Dollars per Ton)
Base	$285.7	--	--	--	--
Fuel Tax: 32.4¢ per Gallon	286.9	$1.203	$1.203	--	$0.30[a]
Segment Tax: No Railroad Response	291.8	6.139	6.139	--	1.52[a]
Segment Tax: 50% Railroad Response	293.9	8.261	6.139	$2.122	0.85[b]
Segment Tax: 100% Railroad Response	295.8	10.140	6.139	4.001	1.60[b]

[a] Calculated with respect to 4,030,379 tons of fertilizer shipped by barge in the base solution.

[b] Calculated with respect to 2,506,806 tons of fertilizer shipped by rail from New Orleans, Louisiana and central Florida to demand regions with directly competing barge service from these same origins in the segment tax, no railroad response solution.

Table 21 compares the total tax collected by each user charge to the total change in transportation and handling cost relative to the 1985 base solution. Under the fuel and segment taxes, assuming no railroad response, over 93% of the change in total cost is attributable to the tax collected. This indicates that competing transportation modes are not receiving a windfall benefit from either one of the basic fuel or segment taxes. However, when varying degrees of railroad response are associated with these user charges, the additional revenue collected by competing modes rises considerably. By the time the railroad industry has responded 100%, almost 39% of the model's total change in transportation cost is collected by the railroad industry. Table 22 shows that the increase in competing mode revenue is not due to large shifts in modal shares. In fact, very little barge traffic shifts to competing modes under any waterway user charge alternative. In the most severe case, the 100% OMRC recovery segment tax, the barge industry loses approximately 7.8% of its base solution traffic to competing modes, while in the least severe case, the 32.4¢ per gallon fuel tax, only 3.0% of barge traffic shifts to other modes. All other user charge taxes produce shifts which lie within this 3.0-7.8% range; thus, indicating that shifts in traffic from the barge mode to other modes remain fairly stable regardless of the type of user charge tax imposed.

Tables 23 through 27 present aggregate revenue and tax collected under 1985 user charges. These revenues and taxes, reported by fertilizer and mode, exhibit relatively small changes between user charge scenarios.

Table 21

Components of 1985 User Charge Induced Transportation and Handling Cost Increases (Millions of Dollars)

User Charge Scenario	Change in Total Cost[a]	Tax Collected	Taxes Collected as a Percent of Change in Cost
Fuel Tax: 32.4¢ per Gallon	\$1.203	\$1.169	97
Segment Tax: No Railroad Response	6.139	5.736	93
Segment Tax: 50% Railroad Response	8.261	5.882	71
Segment Tax: 100% Railroad Response	10.140	6.161	61

[a] Calculated with respect to the total transportation and handling cost of \$285.7 million in the base scenario containing no user charges.

Table 22

Projected Total Tons of Fertilizer Shipped by Mode under Each 1985 User Charge Scenario (Millions of Tons)

User Charge Scenario	Barge	Rail	Truck	Pipeline	Total
Base	4.030	9.742	7.767	0.586	22.125
Fuel Tax: 32.4¢ per Gallon	3.910	9.766	7.891	0.599	22.166[a]
Segment Tax: No Railroad Response	3.718	9.916	7.933	0.599	22.166[a]
Segment Tax: 50% Railroad Response	3.758	9.881	7.927	0.599	22.166[a]
Segment Tax: 100% Railroad Response	3.873	9.793	7.901	0.599	22.166[a]

[a] More urea is shipped to manufacture nitrogen solutions than in the base scenario.

Table 23

Revenue Collected by Mode and Fertilizer under the 1985 Base Scenario (Millions of Dollars)

Mode	Urea	Nitrogen Solutions	Ammonium Nitrate	Ammoniated Phosphates	Triple Superphosphate	Total
Rail	$15.4	$15.8	$5.1	$88.0	$41.4	$165.8
Truck	7.2	28.4	9.0	5.2	3.1	52.9
Barge-Rail	4.5	0.5	-	29.6	2.2	36.9
Barge-Truck	4.4	10.2	-	4.4	1.1	20.1
Pipe-Rail	-	0.0	-	-	-	0.0
Pipe-Truck	-	9.9	-	-	-	9.9
Total	31.5	64.8	14.2	127.3	47.9	285.7

Table 24

Revenue and Tax Collected by Mode and Fertilizer under the 1985 32.4¢ per Gallon Fuel Tax Scenario (Millions of Dollars)

Mode	Urea	Nitrogen Solutions	Ammonium Nitrate	Ammoniated Phosphates	Triple Superphosphate	Total
Rail	$16.0	$15.9	$5.1	$88.0	$41.4	$166.5
Truck	7.2	29.1	9.0	5.2	3.1	53.7
Barge-Rail	4.8	0.5	-	30.0	2.2	37.6
Barge-Truck	4.5	9.0	-	4.4	1.1	19.0
Pipe-Rail	-	0.0	-	-	-	0.0
Pipe-Truck	-	10.1	-	-	-	10.1
Total	32.4	64.7	14.2	127.7	47.9	286.9

Table 25

Revenue and Tax Collected by Mode and Fertilizer under the 1985
100% OMRC Recovery Segment Tax Scenario (Millions of Dollars)

Mode	Urea	Nitrogen Solutions	Ammonium Nitrate	Ammoniated Phosphates	Triple Superphosphate	Total
Rail	$16.8	$15.9	$5.1	$89.8	$44.3	$172.0
Truck	7.6	29.1	9.0	5.2	3.1	54.1
Barge-Rail	4.6	0.5	-	29.8	0.6	35.5
Barge-Truck	4.5	8.9	-	6.7	0.0	20.1
Pipe-Rail	-	0.0	-	-	-	0.0
Pipe-Truck	-	10.1	-	-	-	10.1
Total	33.4	64.7	14.2	131.6	48.0	291.8

Table 26

Revenue and Tax Collected by Mode and Fertilizer under the 1985 100% OMRC Recovery Segment Tax, 50% Railroad Response Scenario (Millions of Dollars)

Mode	Urea	Nitrogen Solutions	Ammonium Nitrate	Ammoniated Phosphates	Triple Superphosphate	Total
Rail	$16.4	$15.9	$5.1	$91.1	$44.5	$173.1
Truck	7.5	29.1	9.0	5.2	3.2	54.1
Barge-Rail	4.7	0.5	-	30.3	0.9	36.5
Barge-Truck	4.6	8.9	-	6.5	0.0	20.1
Pipe-Rail	-	0.0	-	-	-	0.0
Pipe-Truck	-	10.1	-	-	-	10.1
Total	33.3	64.7	14.2	133.1	48.6	293.9

Table 27

Revenue and Tax Collected by Mode and Fertilizer under the 1985 100% OMRC Recovery Segment Tax, 100% Railroad Response Scenario (Millions of Dollars)

Mode	Urea	Nitrogen Solutions	Ammonium Nitrate	Ammoniated Phosphates	Triple Superphosphate	Total
Rail	$16.4	$15.9	$5.1	$91.7	$42.4	$171.6
Truck	7.2	29.1	9.0	5.2	3.2	53.8
Barge-Rail	4.7	0.5	-	31.5	2.4	39.1
Barge-Truck	4.9	8.9	-	6.2	1.2	21.1
Pipe-Rail	-	0.0	-	-	-	0.0
Pipe-Truck	-	10.1	-	-	-	10.1
Total	33.2	64.7	14.2	134.6	49.2	295.8

Changes are small for most individual fertilizer-mode combinations as was the case for total fertilizer shipments presented in Table 20.

Tax collected by river under each user charge scenario is given in Tables 28 through 31 for each fertilizer. The amount of tax collected under each of the segment tax user charges remains relatively stable for all fertilizers except triple superphosphate. An additional 93,649 tons of triple superphosphate are shipped by barge under the 100% OMRC recovery segment tax, 100% railroad response user charge than under the 100% OMRC recovery segment tax with no railroad response, resulting in a six fold increase in taxes collected associated with these shipments.

Under the 32.4¢ per gallon fuel tax, nitrogen solutions generate only slightly more tax than the 100% OMRC segment tax. However, total taxes collected for dry fertilizer shipments are only a fraction what they were under the segment tax; one-half for triple superphosphate, and only one-tenth for urea and ammoniated phosphates. The reason for this is that the fuel tax is levied only on fuel consumed to backhaul fertilizer as was discussed previously in the DATA section.

Table 32 presents total tax collected for all fertilizer shipments by river for each 1985 user charge scenario. Under the fuel tax, the lower Mississippi River accounts for over half of all taxes collected. However, under segment tax scenarios, user charges collected from the upper and lower Mississippi Rivers each account for approximately 30% of all taxes collected.

Finally, Table 33 presents revenue collected by mode under each 1985 user charge scenario. This table essentially combines and summarizes

Table 28

Tax Collected from Urea Shipments by River Segment under Each 1985 User Charge Scenario

River Segment	Fuel Tax: 32.4¢ per Gallon	Segment Tax: No Railroad Response	Segment Tax: 50% Railroad Response	Segment Tax: 100% Railroad Response
Upper Mississippi	$18,132	$387,995	$387,995	$380,743
Middle Mississippi	12,588	111,162	112,824	112,824
Lower Mississippi	51,331	311,636	327,098	340,491
Arkansas	0	0	0	0
Ohio	3,586	23,373	27,195	30,192
Missouri	0	0	0	0
Illinois	2,482	42,731	42,731	42,731
Total	88,119	876,897	897,843	906,981

Table 29

Tax Collected from Ammoniated Phosphate Shipments by River Segment under Each 1985 User Charge Scenario

River Segment	Fuel Tax: 32.4¢ per Gallon	Segment Tax: No Railroad Response	Segment Tax: 50% Railroad Response	Segment Tax: 100% Railroad Response
Upper Mississippi	$45,443	$1,105,796	$1,101,430	$1,133,728
Middle Mississippi	43,560	401,193	405,327	411,052
Lower Mississippi	170,352	1,173,469	1,173,469	1,175,652
Arkansas	9,000	539,460	539,460	539,460
Ohio	6,344	60,238	56,415	53,418
Missouri	112,796	814,711	913,434	980,473
Illinois	5,592	147,686	147,686	147,686
Total	393,087	4,242,553	4,337,221	4,441,469

Table 30

Tax Collected from Triple Superphosphate Shipments by River Segmentunder Each 1985 User Charge Scenario

River Segment	Fuel Tax: 32.4¢ per Gallon	Segment Tax: No Railroad Response	Segment Tax: 50% Railroad Response	Segment Tax: 100% Railroad Response
Upper Mississippi	$3,457	$26,637	$26,637	$81,697
Middle Mississippi	2,488	3,833	5,775	112,824
Lower Mississippi	8,120	8,879	13,884	56,172
Arkansas	0	0	0	0
Ohio	0	0	0	0
Missouri	5,837	0	23,182	73,256
Illinois	0	0	0	42,731
Total	19,902	39,349	69,478	234,595

Table 31

Tax Collected from Nitrogen Solutions Shipments by River Segment under Each 1985 User Charge Scenario

River Segment	Fuel Tax: 32.4¢ per Gallon	Segment Tax: No Railroad Response	Segment Tax: 50% Railroad Response	Segment Tax: 100% Railroad Response
Upper Mississippi	$17,233	$37,728	$37,728	$37,728
Middle Mississippi	54,785	48,055	48,055	48,055
Lower Mississippi	422,876	351,238	351,238	351,238
Arkansas	--	--	--	--
Ohio	145,858	97,432	97,432	97,432
Missouri	0	0	0	0
Illinois	27,623	43,142	43,142	43,142
Total	668,375	577,595	577,595	577,595

Table 32

Total Tax Collected from Fertilizer Shipments by River Segment under Each 1985 User Charge Scenario

River Segment	Fuel Tax: 32.4¢ per Gallon	Segment Tax: No Railroad Response	Segment Tax: 50% Railroad Response	Segment Tax: 100% Railroad Response
Upper Mississippi	$84,265	$1,558,156	$1,553,790	$1,633,896
Middle Mississippi	113,421	564,243	571,981	595,401
Lower Mississippi	652,679	1,845,222	1,865,689	1,923,553
Arkansas	9,000	539,460	539,460	539,460
Ohio	155,788	181,043	181,042	181,042
Missouri	118,633	814,711	936,616	1,053,729
Illinois	35,697	233,559	233,559	233,559
Total	1,169,483	5,736,394	5,882,137	6,160,640

Table 33

Total Revenue Collected by Mode under
Each 1985 User Charge Senario

Mode	Base	Fuel Tax: 32.4¢ per Gallon	Segment Tax: No Railroad Response	Segment Tax: 50% Railroad Response	Segment Tax: 100% Railroad Response
Rail	$165.8	$166.5	$172.0	$173.1	$171.6
Truck	52.9	53.7	54.1	54.1	53.8
Barge	57.0	55.4	50.0	50.7	54.1
Pipeline	9.9	10.1	10.1	10.1	10.1
Total	285.7	285.7	286.1	288.0	289.6

Tables 23 through 27, and removes the tax presented in Tables 28 through 31. Under the most severe user charge, the 100% OMRC segment tax, the barge industry loses 12.3% its base solution revenue, while under the 32.4¢ per gallon fuel tax scenario, only 2.8% of the barge industry's base solution revenue is lost. Also, as railroad response increases, the barge industry regains lost revenue. By the time the railroad industry has responded 100%, barge industry revenue losses are down to only 5.1% of base solution revenues.

One measure of the sensitivity of the fertilizer industry to each type of waterway user charge is the price elasticity of demand for barge service. This elasticity measures the percentage change in demand for barge service given a percentage change in barge rates, and can be expressed mathematically as:

$$\varepsilon = -\frac{\partial Q}{\partial P} \cdot \frac{P}{Q} \tag{28}$$

where

ε = The price elasticity of demand for fertilizer barge service

P = The price of fertilizer barge service

Q = The quantity of barge service demanded at price P

$\frac{\partial Q}{\partial P}$ = The rate of change in the demand for barge service with respect to price p and quantity Q

Since the exact demand function for fertilizer barge service is not known, point elasticity (28) must be approximated by arc-elasticity (29).

In this approximation, the demand curve for fertilizer barge service is estimated as a straight line between two points on the actual barge service demand curve, with arc-elasticity being calculated at the midpoint of the line connecting these two points.

$$\varepsilon_i' = -\frac{\Delta Q}{\Delta P} \cdot \frac{\frac{(P_B + P_T)}{2}}{\frac{(Q_B + Q_T)}{2}} = -\frac{\Delta Q}{\Delta P} \cdot \frac{(P_B + P_T)}{(Q_B + Q_T)} \ [24] \qquad (29)$$

where

ε_i' = The price elasticity of demand for fertilizer barge service between a given origin and river warehouse or tank terminal destination i

P_B = The price of fertilizer barge service between the specified origin and destination in the base solution (i.e., no user charge tax)

P_T = The price of fertilizer barge service between the specified origin and destination under a specified user charge tax.

Q_B = The quantity of fertilizer shipped between the specified origin and destination in the base solution.

Q_T = The quantity of fertilizer shipped between the specified origin and destination under a specified user charge tax

$\Delta P = P_B - P_T$

$\Delta Q = Q_B - Q_T$

The demand for fertilizer barge service normally varies inversely with price, thus the arc-elasticity calculated by equation (29) is expected to be non-negative. Also, the magnitude of ε_i' indicates the following relationships between price and quantity:

$\varepsilon_i' > 1$ --Elastic demand--A given percentage change in price results in a greater percentage change in quantity demanded

$\varepsilon_i' = 1$ --Unit elasticity--The percentage change in price and quantity are equal

$0 < \varepsilon_i' < 1$ --Inelastic demand--A given percentage change in price results in a smaller percentage change in quantity demanded.

$\varepsilon_i' = 0$ --Perfectly inelastic--The change in price results in no change in demand

$\varepsilon_i' < 0$ --An inferior commodity--Price and quantity are directly related such that a decrease in price results in a decrease in quantity demanded. Implies the substitution of another commodity for the original commodity

Theoretically, elasticities are calculated ceteris paribus, that is, holding everything constant except the relevant price. Thus in the case of this study, the price elasticity of demand for fertilizer barge service for a given fertilizer between a specified origin and destination should be calculated holding all prices constant, except the price for barge service associated with the specified origin-destination pair. This price would be increased by the appropriate user charge tax, the model rerun, and an elasticity calculated based on the new user charge solution.

However, this method is too expensive and time consuming to be practical. Thus, the ceteris paribus restriction must be relaxed slightly to allow all barge rates to be modified simultaneously while modelling a particular user charge scenario. The model then is run only once for a particular user charge to estimate elasticities. Therefore, the author realizes that the assumptions under which elasticities are actually calculated in this study vary slightly from some of the theoretical assumptions, but given the time and budget constraints of this study, are reasonably accurate.

Table 34 reveals several interesting results about price elasticities of demand calculated from 1985 computer solutions. First, the overall unresponsiveness of the fertilizer industry to the 32.4¢ per gallon fuel tax and 100% OMRC recovery segment tax is indicated by the large number of "0" (i.e., perfectly inelastic) entries in the table. Secondly, supply point-river destination pairs exhibiting negative elasticities indicate the substitution in demand of one fertilizer for another at a given river destination, and/or the shift in demand for a given fertilizer from one river to another. For example, an elasticity of 15.13 for urea shipped from New Orleans, Louisiana to Chester, Illinois indicates that a 1% increase in fertilizer barge rates results in a 15.13% reduction in urea shipments between New Orleans and Chester. At the same time, this 1% increase in fertilizer barge rates results in a 5.22% increase in ammoniated phosphate shipments between these points. In essence, ammoniated phosphate is being substituted for urea at a rate slower than urea is being removed from this route. These substitutions and shifts will be discussed in detail later.

Table 34

Price Elasticities of Demand for 1985 Fertilizer Barge Service from New Orleans, Louisiana and Central Florida to River Destinations under a 32.4¢ per Gallon Fuel Tax and a 100% OMRC Recovery Segment Tax

River Destination	Urea from New Orleans		Ammoniated Phosphates from New Orleans		Triple Superphosphate from Florida		Nitrogen Solutions from New Orleans	
	Fuel	Segment	Fuel	Segment	Fuel	Segment	Fuel	Segment
Friars Point, Mississippi	0.0	0.0	0.0	0.0	0.0	0.0	-	-
Barfield, Arkansas	0.0	0.0	0.0	0.0	0.0	0.0	-	-
Birds Point, Missouri	-	-	-	-	-	-	2.26	2.68
Chester, Illinois	0.0	15.13	0.0	-5.22	0.0	0.0	-	-
Herculaneum, Missouri	-	-	-	-	-	-	0.0	0.0
Granite City, Illinois	0.0	0.0	0.0	-1.61	0.0	0.0	1.03	1.21
Palmyra, Missouri	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Burlington, Iowa	0.0	0.0	0.0	-10.82	0.0	37.20	0.0	0.0
Clinton, Iowa	-3.98	-0.20	1.25	0.06	0.0	0.0	0.0	0.0
Prairie du Chien, Wisconsin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pine Bend, Minnesota	-2.61	0.44	0.0	0.0	0.0	9.43	1.23	0.0
Catoosa, Oklahoma	0.0	0.0	0.0	0.0	0.0	0.0	-	-
South Point, Ohio	-	-	-	-	-	-	0.0	0.0

Table 34--Continued

River Destination	Urea from New Orleans		Ammoniated Phosphates from New Orleans		Triple Superphosphate from Florida		Nitrogen Solutions from New Orleans	
	Fuel	Segment	Fuel	Segment	Fuel	Segment	Fuel	Segment
Cincinnati, Ohio	0.0	1.15	-0.24	-0.59	0.0	0.0	0.0	0.0
Owensboro, Kentucky	0.0	14.03	0.0	-2.42	0.0	0.0	0.0	0.0
Louisville, Kentucky	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Boonville, Missouri	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kansas City, Kansas	0.0	0.0	-0.99	-0.13	0.0	0.0	0.0	0.0
Mound City, Missouri	0.0	0.0	0.0	0.0	0.0	0.0	-	-
Nebraska City, Nebraska	-	-	-	-	-	-	0.0	0.0
Council Bluffs, Iowa	0.0	0.0	0.0	-0.71	0.0	19.91	-	-
Sioux City, Iowa	0.0	0.0	0.0	5.10	0.0	18.63	0.0	0.0
Meredosia, Illinois	-	-	-	-	-	-	0.0	0.0
Pekin, Illinois	0.0	0.0	0.0	0.0	0.0	0.0	-2.18	-2.24
Joliet, Illinois	0.0	0.0	0.0	-6.35	0.0	0.0	11.13	10.73
Calumet City, Illinois	0.0	0.0	0.0	0.0	0.0	0.0	-	-

Price elasticities of demand are calculated for each fertilizer by river segment also (30). River destination elasticities (29) are weighted by the average tons of fertilizer shipped in the base and appropriate user charge solution through each destination on a given river.

$$\varepsilon_r = \frac{\dfrac{\Sigma\ \varepsilon_i \cdot (Q_i^{\,B} + Q_i^{\,T})}{2}}{\dfrac{\Sigma\ (Q_i^{\,B} + Q_i^{\,T})}{2}} = \frac{\Sigma\ \varepsilon_i \cdot\ (Q_i^{\,B} + Q_i^{\,T})}{\Sigma\ (Q_i^{\,B} + Q_i^{\,T})}\ [24] \qquad (30)$$

where

ε_r = The price elasticity of demand for fertilizer shipped between a given supply point and river segment

$Q_i^{\,B}$ = The quantity of fertilizer shipped between the specified origin and river segment i in the base solution

$Q_i^{\,T}$ = The quantity of fertilizer shipped between the specified origin and river segment in a given user charge solution

Table 35 presents price elasticities of demand from New Orleans and central Florida to each river by type of fertilizer. Once again, the overall unresponsiveness of the fertilizer industry to the basic fuel and segment user charges is indicated by the large number of "0" elasticities. In fact, the lower Mississippi and Arkansas rivers are perfectly inelastic under both scenarios. Also, triple superphosphate is perfectly inelastic on all rivers under the fuel tax user charge.

Also revealed in Table 35 are substitutions and shifts in demand for fertilizer barge service between rivers. For example, under the 32.4¢ per

Table 35

Price Elasticities of Demand for 1985 Fertilizer Barge Service from New Orleans, Louisiana and Central Florida to Each River Segment under a 32.4¢ per Gallon Fuel Tax and a 100% OMRC Recovery Segment Tax

River Segment	Urea from New Orleans		Ammoniated Phosphates from New Orleans		Triple Superphosphate from Florida		Nitrogen Solutions from New Orleans	
	Fuel	Segment	Fuel	Segment	Fuel	Segment	Fuel	Segment
Upper Mississippi	-1.84	0.17	0.27	-0.32	0.0	18.87	1.00	0.72
Middle Mississippi	0.0	1.53	0.0	-2.08	0.0	0.0	1.60	1.90
Lower Mississippi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Arkansas	0.0	0.0	0.0	0.0	0.0	0.0	-	-
Ohio	0.0	2.44	-0.17	-1.08	0.0	0.0	0.0	0.0
Missouri	0.0	0.0	0.23	1.65	0.0	19.55	0.0	0.0
Illinois	0.0	0.0	0.0	-2.10	0.0	0.0	2.77	2.59

gallon fuel tax, the upper Mississippi River substitutes urea barge service for ammoniated phosphates barge service, while simultaneously, the demand for ammoniated phosphates barge service shifts from the upper Mississippi and Missouri Rivers to the Ohio River. A detailed analysis of these substitutions and shifts is presented later for each user charge scenario.

Referring to Table 22 again, we see that as the user charge becomes more severe, more barge traffic is lost to competing modes. Under the 32.4¢ per gallon fuel tax, only 120,359 tons of fertilizer are lost, while under the segment tax, 312,486 tons are lost to competing modes. On the other hand, total barge traffic increases as railroad response rises for a given user charge tax. In the 100% OMRC recovery segment tax, 50% railroad response case, 40,529 tons of fertilizer traffic shift back to the barge mode, while in the 100% OMRC recovery segment tax, 100% railroad response case, 155,110 tons shift back to the barge mode. Thus, the 32.4¢ per gallon fuel tax and 100% OMRC recovery segment tax, 100% railroad response scenarios interestingly yield approximately the same results.

Table 36 presents total barge traffic by river under each 1985 user charge scenario. Note that for many rivers, shifts in total barge traffic are very small or non-existent, thus corroborating the elasticities calculated earlier. Tables 37 through 40 report barge traffic by fertilizer and river for each 1985 user charge scenario and reveals another interesting phenomenon. As the user charge tax becomes more severe, individual rivers do not necessarily follow the trend set by total barge traffic. For example, Table 38 shows that urea traffic under the

Table 36

Projected Total Tons of Fertilizer Shipped by Barge to River Segments under Each 1985 User Charge Scenario

River Segment	Base	Fuel Tax: 32.4¢ per Gallon	Segment Tax: No Railroad Response	Segment Tax: 50% Railroad Response	Segment Tax: 100% Railroad Response
Lower Mississippi	71,891	71,891	71,891	71,891	71,891
Middle Mississippi	334,345	311,990	347,815	347,815	347,815
Upper Mississippi	1,320,660	1,324,464	1,294,027	1,284,717	1,328,415
Arkansas	90,000	90,000	90,000	90,000	90,000
Ohio	821,629	822,500	822,500	822,500	822,500
Missouri	817,158	821,095	522,969	572,808	643,691
Illinois	574,696	468,080	568,691	568,691	568,691
Total	4,030,379	3,910,020	3,717,893	3,758,422	3,873,003

Table 37

Projected Tons of Nitrogen Solutions Shipped by Barge to River Segments under Each 1985 User Charge Scenario

River Segment	Base	Fuel Tax: 32.4¢ per Gallon	Segment Tax: No Railroad Response	Segment Tax: 50% Railroad Response	Segment Tax: 100% Railroad Response
Upper Mississippi	31,953	26,637	26,637	26,637	26,637
Middle Mississippi	103,551	81,196	81,196	81,196	81,196
Lower Mississippi	0	0	0	0	0
Arkansas	--	--	--	--	--
Ohio	432,500	432,500	432,500	432,500	432,500
Missouri	0	0	0	0	0
Illinois	261,803	155,187	155,187	155,187	155,187
Total	829,807	695,520	695,520	695,520	695,520

Table 38

Projected Tons of Urea Shipped by Barge to River Segments under Each 1985 User Charge Scenario

River Segment	Base	Fuel Tax: 32.4¢ per Gallon	Segment Tax: No Railroad Response	Segment Tax: 50% Railroad Response	Segment Tax: 100% Railroad Response
Upper Mississippi	359,721	373,649	344,725	344,725	344,725
Middle Mississippi	83,772	83,772	68,383	83,772	83,772
Lower Mississippi	0	0	0	0	0
Arkansas	0	0	0	0	0
Ohio	138,894	138,894	97,145	112,374	138,894
Missouri	0	0	0	0	0
Illinois	106,848	106,848	106,848	106,848	106,848
Total	689,235	703,163	617,101	647,719	674,239

Table 39

Projected Tons of Ammoniated Phosphates Shipped by Barge to River Segments under Each 1985 User Charge Scenario

River Segment	Base	Fuel Tax: 32.4¢ per Gallon	Segment Tax: No Railroad Response	Segment Tax: 50% Railroad Response	Segment Tax: 100% Railroad Response
Upper Mississippi	853,136	848,328	905,083	895,773	881,203
Middle Mississippi	147,022	147,022	198,236	182,847	182,847
Lower Mississippi	71,891	71,891	71,891	71,891	71,891
Arkansas	90,000	90,000	90,000	90,000	90,000
Ohio	250,235	251,106	292,855	277,626	251,106
Missouri	781,777	785,714	522,969	562,897	608,310
Illinois	206,045	206,045	306,656	306,656	306,656
Total	2,400,106	2,400,106	2,387,690	2,387,690	2,392,013

Table 40

Projected Tons of Triple Superphosphate Shipped by Barge to River Segments under Each 1985 User Charge Scenario

River Segment	Base	Fuel Tax: 32.4¢ per Gallon	Segment Tax: No Railroad Response	Segment Tax: 50% Railroad Response	Segment Tax: 100% Railroad Response
Upper Mississippi	75,850	75,850	17,582	17,582	75,850
Middle Mississippi	0	0	0	0	0
Lower Mississippi	0	0	0	0	0
Arkansas	0	0	0	0	0
Ohio	0	0	0	0	0
Missouri	35,381	35,381	0	9,911	35,381
Illinois	0	0	0	0	0
Total	111,231	111,231	17,582	27,493	111,231

32.4¢ per gallon user charge tax rises on the upper Mississippi River rather than falls as does total fertilizer barge traffic. Similar situations occur for ammoniated phosphates. These and other implications of each waterway user charge are discussed below.

Analysis of the 32.4¢ per gallon fuel tax

The most dramatic impact of the 32.4¢ per gallon fuel tax is on nitrogen solutions. This is the result of the fuel tax being assessed on fuel consumed for the entire trip rather than just the return trip from New Orleans, as is the case for dry fertilizers. Under the fuel tax, it becomes more economical for Midwestern demand regions to receive nitrogen solutions manufactured at Midwestern production facilities by truck or pipeline, rather than by barge from New Orleans. A total of 134,287 tons of nitrogen solutions is lost to competing modes due to this additional manufacturing in Illinois, Iowa, and Oklahoma. Breaking this down by river, the upper Mississippi River loses 5,316 tons to pipeline, the middle Mississippi River loses 13,500 to pipeline and 8,855 tons to truck, and the Illinois River loses 106,616 tons to truck. The increase in short distance nitrogen solutions trucking in the Midwest forces some nitrogen solutions demand formerly supplied by pipeline from Midwestern production facilities to now be supplied by pipeline from more distant facilities.

Nitrogen solutions market pattern shifts affect other commodities also. Sufficient ammonium nitrate is available to meet the increase in

Midwestern nitrogen solutions manufacturing, but urea supplies are not adequate. Thus, 40,877 additional tons of urea are shipped by rail from outlying Midwestern supply points to augment the urea supplies of those production facilities now manufacturing more nitrogen solutions than in the base scenario. Since these additional urea shipments disturb the marketing balance in the Midwest, several other minor shifts in rail and truck marketing are necessary to establish a new equilibrium. Also, 13,928 additional tons of urea are barged from New Orleans to the upper Mississippi River to satisfy demand regions whose former urea supply is now manufactured into nitrogen solutions. The impact of the fuel tax, however, is not severe enough to force this urea to be supplied by rail. Consequently, since some warehouses on the upper Mississippi River are operating at maximum capacity, 4,808 tons of ammoniated phosphates are forced to shift to the Ohio and Missouri Rivers to make room for the additional urea. Finally, note that through out this complex equilibrium seeking process, triple superphosphate barge shipments are undisturbed.

Analysis of the 100% OMRC recovery segment tax

The impact of the 100% OMRC recovery segment tax is more pronounced than the 32.4¢ per gallon fuel tax as is exhibited by the fact that total fertilizer barge shipments drop almost two and one-half times as much under the segment tax than under the fuel tax. Interestingly, nitrogen solutions react in exactly the same manner to the segment tax as they do to the fuel tax. However, this result should not be too surprising, since the tax imposed on liquid fertilizer shipments is very similar in magnitude under both user charge scenarios. Also, as in the fuel tax case, an additional 40,877 tons of urea are shipped to the Midwest from outlying supply points.

Total barge shipments of ammoniated phosphates fall only 12,416 tons, however this small change in total ammoniated phosphate barge marketing is deceiving. Numerous shifts in ammoniated phosphate marketing occur between rivers. The Missouri River loses 258,808 tons of traffic, while the upper Mississippi, middle Mississippi, Ohio, and Illinois Rivers gain 51,947, 51,214, 42,620, and 100,611 tons of ammoniated phosphate barge traffic respectively. Surprisingly however, the Missouri River is not losing its barge traffic directly due to the user charge added to Missouri River barge rates. Barge rates are still cheaper than rail rates on directly competing routes from New Orleans. What one must keep in mind is that the model minimizes total transportation and handling costs for the entire study area, not individual rivers or demand regions. Thus, the supply of ammoniated phosphates at New Orleans is marketed where the greatest savings are realized. In the case of the 100% OMRC recovery segment tax, those savings are no longer as great on the Missouri River as on the upper Mississippi, middle Mississippi, Ohio, and Illinois Rivers, consequently forcing the shifts in ammoniated phosphate marketing described earlier. Since many warehouses on the upper Mississippi, middle Mississippi, Ohio, and Illinois Rivers were operating at capacity in the base scenario, the increase in ammoniated phosphate traffic forces urea out of these warehouses; 15,389 tons on the middle Mississippi River, 14,996 tons on the upper Mississippi River, and 41,749 tons on the Ohio River. These shifts in urea marketing, along with those shifts induced by additional nitrogen solutions manufacturing in the Midwest, set off a chain reaction of minor changes in rail and truck marketing of urea. Some of these changes are felt as far away as Maine which now receives urea from New York rather than Ohio.

Under the segment tax, some triple superphosphate barge rates become more expensive than rail rates such that 93,649 fewer tons of triple superphosphate are shipped by barge on the inland waterway system. The Missouri River loses 35,381 tons and the upper Mississippi River loses 58,268 tons.

Analysis of the 100% OMRC recovery segment tax, 50% railroad response

This discussion describes the impact of a 50% railroad response to a 100% OMRC recovery segment tax. All references to changes or shifts in quantities of fertilizer shipped are relative to the 100% OMRC recovery segment tax computer solution.

The effects of a 50% railroad response are quite limited since the barge industry regains less than 13.0% of total traffic lost due to the segment tax. Examination of individual fertilizer response reveals that ammonium nitrate and nitrogen solutions experience no change in their marketing patterns, while ammoniated phosphates, urea, and triple superphosphate experience only minor changes.

Under the 50% railroad response, greater savings are realized if 39,928 tons of ammoniated phosphates shift back to the Missouri River. The middle Mississippi, upper Mississippi, and Ohio Rivers lose 15,389, 9,310, and 15,229 tons of ammoniated phosphate traffic respectively. These shifts free up warehouse space for additional urea barge traffic. Thus, gains in urea barge traffic are 15,389 tons on the middle Mississippi River, and 15,229 tons on the Ohio River. These shifts in the urea market set off a chain reaction of minor changes in rail and truck marketing patterns which reestablishes the base urea market situation in the northeastern portion of the United States.

Finally, 9,911 additional tons of triple superphosphate are barged on the Missouri River. The 50% railroad response has made a few rail rates more expensive than barge rates allowing a shift in the mode of transportation.

Analysis of the 100% OMRC recovery segment tax, 100% railroad response

This discussion describes the impact of a 100% railroad response to a 100% OMRC recovery segment tax. All references to changes or shifts in quantities of fertilizer shipped are relative to the 100% OMRC recovery segment tax computer solution.

The effects of a 100% railroad response are more pronounced than the 50% railroad response case. The barge industry regains over 49% of total barge traffic lost due to the segment tax. Again, no changes occur for ammonium nitrate or nitrogen solutions, but significant shifts occur in ammoniated phosphate, urea, and triple superphosphate marketing patterns. Total barge shipments of ammoniated phosphates increase by only 4,323 tons, but numerous shifts occur between rivers. Greater savings are now realized by shifting 85,341 tons of ammoniated phosphates back to the Missouri River. To facilitate this shift, the upper Mississippi, middle Mississippi, and Ohio Rivers give up 23,880, 15,389, and 41,749 tons of ammoniated phosphate barge traffic. These shifts free up warehouse space for 57,138 tons of urea. The middle Mississippi River gains 15,389 tons and the Ohio River gains 41,479 tons of urea barge traffic. These shifts allow minor truck and rail marketing pattern shifts to occur which reestablish the base urea market situation in the northeastern United States.

The 100% railroad response has made some triple superphosphate railroad rates more expensive than barge rates. Thus, total barge traffic increases by 93,649 tons; 58,268 tons on the upper Mississippi River and 35,381 tons on the Missouri River, restoring triple superphosphate marketing to the base solution river tonnages. Also, a few minor shifts occur within the triple superphosphate rail industry as a new equilibrium is established in the market.

1990 Base and User Charge Computer Solutions

All user charge solutions generated for 1990 are based on estimated 1990 fertilizer supplies and demands, and estimated 1980 transportation and handling costs. Each user charge scenario modifies the basic 1980 transportation and handling cost structure by increasing barge and/or railroad rates to reflect the desired user charge. The following user charge scenarios are modelled for 1990:

- o 38.1¢ per gallon fuel tax (1990)
- o 100% OMRC recovery segment tax (1990)
- o 100% OMRC recovery segment tax (1990), plus 50% railroad response
- o 100% OMRC recovery segment tax (1990), plus 100% railroad response

See Appendix A for a detailed presentation of fertilizer shipments by mode.

The results of 1990 user charges are very similar to those generated for 1985 user charges. Virtually the same conclusions can be drawn for all the same reasons as before. Table 41 shows that the total base transportation and handling cost of $310,831,996 changes very little under any user charge scenario. The total cost of shipping all fertilizer increases just over 0.6% under the fuel tax and 2.1% under the segment tax. Thus, the average increase in cost per ton paid for fertilizer shipped by barge is $0.39 and $1.40 under the fuel and segment taxes, respectively. The impact of railroad response measured relative to the segment tax scenario is rather small also. The total cost of shipping all fertilizer increases 0.6% under 50% railroad response and 1.2% under 100% railroad response. Therefore, the average cost per ton for fertilizer shipped by rail rises $0.69 and $1.33 for the 50% and 100% railroad response scenarios, respectively.

Table 41

Estimated Total Fertilizer Transportation and Handling Costs Plus User Charges Collected under Each 1990 User Charge Senario (Millions of Dollars Except Where Noted)

User Charge Solution	Total Cost	Total Change in Cost	Cost Change due to User Charge	Cost Change due to Railroad Response	Average Change in Cost (Dollars per Ton)
Base	$310.8	--	--	--	--
Fuel Tax: 38.1¢ per Gallon	312.6	$1.786	$1.786	--	$0.39[a]
Segment Tax: No Railroad Response	317.3	6.443	6.443	--	1.40[a]
Segment Tax: 50% Railroad Response	319.3	8.462	6.443	$2.019	0.69[b]
Segment Tax: 100% Railroad Response	321.2	10.319	6.443	3.876	1.33[b]

[a] Calculated with respect to 4,604,530 tons of fertilizer shipped by barge in the base solution.

[b] Calculated with respect to 2,915,157 tons of fertilizer shipped by rail from New Orleans, Louisiana and central Florida to demand regions with directly competing barge service from these same origins in the segment tax, no railroad response solution.

Table 42 demonstrates that under the fuel and segment taxes, assuming no railroad response, over 91% of the change in total cost is attributable to the tax collected. Thus, competing transportation modes are not receiving a windfall benefit from either the fuel or segment tax. However, when railroad response is associated with the segment tax, the revenue collected by competing modes rises significantly. By the time the railroad industry has responded 100%, almost 38% of the model's total change in transportation cost is collected by the railroad industry.

Table 43 indicates that very little of the additional revenue collected by competing modes is due to shifts in modal shares. In the most severe case, the 100% OMRC recovery segment tax, the barge industry loses 10.1% of its base solution traffic, while in the least severe case, the 38.1¢ per gallon fuel tax, only 7.6% of total barge traffic shifts to other modes.

Aggregate revenue and tax collected under 1990 user charges are shown in Tables 44 through 48. As in the case of 1985 user charges, the stability of the industry is the dominant characteristic found in these tables.

Tables 49 through 52 present total tax collected by river under each 1990 user charge scenario. Again, these results are very similar to 1985 user charge tax results. The amount of tax collected under each of the segment tax user charge scenarios remains quite stable for all fertilizers except triple superphosphate. An additional 51,278 tons of triple superphosphate are shipped by barge under the 100% OMRC recovery segment

Table 42

Components of 1990 User Charge Induced Transportation and Handling Cost Increases (Millions of Dollars)

User Charge Scenario	Change in Total Cost[a]	Tax Collected	Taxes Collected as a Percent of Change in Cost
Fuel Tax: 38.1¢ per Gallon	\$1.786	\$1.631	91
Segment Tax: No Railroad Response	6.443	6.065	94
Segment Tax: 50% Railroad Response	8.462	6.115	72
Segment Tax: 100% Railroad Response	10.319	6.436	62

[a] Calculated with respect to the total transportation and handling cost of \$310.8 million in the base scenario containing no user charges.

Table 43

Projected Total Tons of Fertilizer Shipped by Mode under Each 1990 User Charge Scenario (Millions of Tons)

User Charge Scenario	Barge	Rail	Truck	Pipeline	Total
Base	4.605	10.582	7.454	0.723	23.364
Fuel Tax: 32.4¢ per Gallon	4.257	10.749	7.731	0.727	23.465[a]
Segment Tax: No Railroad Response	4.142	10.829	7.758	0.737	23.465[a]
Segment Tax: 50% Railroad Response	4.146	10.826	7.757	0.737	23.465[a]
Segment Tax: 100% Railroad Response	4.216	10.776	7.736	0.737	23.465[a]

[a] More urea is shipped to manufacture nitrogen solutions than in the base scenario.

Table 44

Revenue Collected by Mode and Fertilizer under the 1990 Base Scenario (Millions of Dollars)

Mode	Urea	Nitrogen Solutions	Ammonium Nitrate	Ammoniated Phosphates	Triple Superphosphate	Total
Rail	\$18.6	\$21.2	\$3.9	\$103.9	\$36.5	\$184.0
Truck	7.8	29.7	4.7	5.4	3.0	50.5
Barge-Rail	7.2	0.5	-	30.3	0.9	39.0
Barge-Truck	5.1	15.6	-	3.5	0.8	25.0
Pipe-Rail	-	0.0	-	-	-	0.0
Pipe-Truck	-	12.4	-	-	-	12.4
Total	38.6	79.3	8.6	143.1	41.2	310.8

Table 45

Revenue and Tax Collected by Mode and Fertilizer under the 1990 38.1¢ per Gallon Fuel Tax Scenario (Millions of Dollars)

Mode	Urea	Nitrogen Solutions	Ammonium Nitrate	Ammoniated Phosphates	Triple Superphosphate	Total
Rail	$20.7	$22.4	$3.9	$104.0	$36.7	$187.6
Truck	8.0	30.6	4.7	5.4	3.0	51.7
Barge-Rail	7.3	0.6	-	30.6	0.7	39.2
Barge-Truck	5.0	12.4	-	3.8	0.8	21.7
Pipe-Rail	-	0.0	-	-	-	0.0
Pipe-Truck	-	12.4	-	-	-	12.4
Total	41.0	78.3	8.6	143.5	41.2	312.6

Table 46

Revenue and Tax Collected by Mode and Fertilizer under the 1990 100% OMRC Recovery Segment Tax Scenario (Millions of Dollars)

Mode	Urea	Nitrogen Solutions	Ammonium Nitrate	Ammoniated Phosphates	Triple Superphosphate	Total
Rail	$20.7	$22.9	$3.9	$105.0	$38.0	$190.6
Truck	8.5	30.5	4.7	5.4	3.0	52.1
Barge-Rail	7.2	0.5	-	31.6	0.2	39.5
Barge-Truck	5.8	11.6	-	5.1	0.0	22.6
Pipe-Rail	-	0.0	-	-	-	0.0
Pipe-Truck	-	12.6	-	-	-	12.6
Total	42.2	78.1	8.6	147.1	41.2	317.3

Table 47

Revenue and Tax Collected by Mode and Fertilizer under the 1990 100% OMRC Recovery Segment Tax, 50% Railroad Response Scenario (Millions of Dollars)

Mode	Urea	Nitrogen Solutions	Ammonium Nitrate	Ammoniated Phosphates	Triple Superphosphate	Total
Rail	$20.9	$22.9	$3.9	$106.4	$38.3	$192.3
Truck	8.4	30.5	4.7	5.4	3.1	52.0
Barge-Rail	7.3	0.5	-	31.9	0.3	40.1
Barge-Truck	5.7	11.6	-	5.0	0.0	22.3
Pipe-Rail	-	0.0	-	-	-	0.0
Pipe-Truck	-	12.6	-	-	-	12.6
Total	42.2	78.1	8.6	148.6	41.7	319.3

Table 48

Revenue and Tax Collected by Mode and Fertilizer under the 1990 100% OMRC Recovery Segment Tax, 100% Railroad Response Scenario (Millions of Dollars)

Mode	Urea	Nitrogen Solutions	Ammonium Nitrate	Ammoniated Phosphates	Triple Superphosphate	Total
Rail	$20.9	$22.9	$3.9	$107.0	$37.3	$192.0
Truck	8.1	30.5	4.7	5.4	3.1	51.8
Barge-Rail	7.6	0.5	-	33.6	1.0	42.8
Barge-Truck	5.6	11.6	-	4.0	0.8	22.0
Pipe-Rail	-	0.0	-	-	-	0.0
Pipe-Truck	-	12.6	-	-	-	12.6
Total	42.2	78.1	8.6	150.1	42.2	321.2

Table 49

Tax Collected from Urea Shipments by River Segment
under Each 1990 User Charge Scenario

River Segment	Fuel Tax: 38.1¢ per Gallon	Segment Tax: No Railroad Response	Segment Tax: 50% Railroad Response	Segment Tax: 100% Railroad Response
Upper Mississippi	$26,176	$435,786	$445,844	$435,668
Middle Mississippi	19,605	359,439	359,439	359,439
Lower Mississippi	78,654	314,887	314,887	322,283
Arkansas	0	0	0	0
Ohio	4,980	19,165	19,165	20,538
Missouri	1,854	0	0	0
Illinois	3,482	80,771	80,771	80,771
Total	134,751	1,210,048	1,220,106	1,218,699

Table 50

Tax Collected from Ammoniated Phosphate Shipments by River Segment under Each 1990 User Charge Scenario

River Segment	Fuel Tax: 38.1¢ per Gallon	Segment Tax: No Railroad Response	Segment Tax: 50% Railroad Response	Segment Tax: 100% Railroad Response
Upper Mississippi	$57,937	$1,108,644	$1,123,314	$1,136,014
Middle Mississippi	53,873	950,466	960,091	1,003,583
Lower Mississippi	202,611	847,250	850,151	851,162
Arkansas	10,530	255,240	255,240	255,240
Ohio	4,370	30,755	30,755	19,440
Missouri	113,379	816,754	816,754	999,623
Illinois	8,584	115,891	115,891	115,891
Total	451,284	4,125,000	4,152,196	4,380,953

Table 51

Tax Collected from Triple Superphosphate Shipments by River Segmentunder Each 1990 User Charge Scenario

River Segment	Fuel Tax: 38.1¢ per Gallon	Segment Tax: No Railroad Response	Segment Tax: 50% Railroad Response	Segment Tax: 100% Railroad Response
Upper Mississippi	$1,073	$7,742	$7,742	$27,698
Middle Mississippi	1,327	2,783	4,694	27,452
Lower Mississippi	4,414	2,005	3,542	20,516
Arkansas	0	0	0	0
Ohio	0	0	0	0
Missouri	3,770	0	9,653	43,102
Illinois	0	0	0	0
Total	10,584	12,530	25,631	118,768

Table 52

Tax Collected from Nitrogen Solutions Shipments by River Segment under Each 1990 User Charge Scenario

River Segment	Fuel Tax: 38.1¢ per Gallon	Segment Tax: No Railroad Response	Segment Tax: 50% Railroad Response	Segment Tax: 100% Railroad Response
Upper Mississippi	$84,965	$121,529	$121,529	$121,529
Middle Mississippi	112,738	180,446	180,446	180,446
Lower Mississippi	624,502	306,283	306,283	306,283
Arkansas	--	--	--	--
Ohio	171,415	58,212	58,212	58,212
Missouri	0	0	0	0
Illinois	40,423	50,674	50,674	50,674
Total	1,034,043	717,144	717,144	717,144

tax, 100% railroad response scenario than under the segment tax scenario with no railroad response, thus collecting over nine times as much tax.

Nitrogen solutions generate considerably more taxes under the fuel tax scenario than under the segment tax scenario since the fuel tax is approximately twice the segment tax on the lower Mississippi and Ohio Rivers. However, the amount of total taxes collected for dry fertilizers are only about one-tenth what they were under the segment tax scenario due to the fuel tax assessment technique applied to dry fertilizers described earlier.

Table 53 presents total tax collected for all fertilizers by river for each 1990 user charge scenario. Under the fuel tax, the lower Mississippi River generates over half of all tax collected. However, under the segment tax scenarios, the upper, middle, and lower Mississippi River segments each account for about 25% of all taxes collected.

Table 54 presents revenue collected by mode under each 1990 user charge scenario. This table is similar to Table 33 summarizing 1985 modal revenue, and reveals many similar results. Under the most severe user charge, the 100% OMRC segment tax, the barge industry loses 12.4 % of its base solution revenue, while under the 38.1¢ per gallon fuel tax scenario, only 7.2% of the barge industry's base solution revenue is lost. Again, as railroad response increases, the barge industry regains lost revenue. By the time the railroad industry has responded 100%, barge industry revenue losses are down to only 8.6% of base solution revenues.

Price elasticities of demand for fertilizer barge service calculated from 1990 computer solutions are presented in Table 55. These

Table 53

Total Tax Collected from Fertilizer Shipments by River Segment under Each 1990 User Charge Scenario

River Segment	Fuel Tax: 32.4¢ per Gallon	Segment Tax: No Railroad Response	Segment Tax: 50% Railroad Response	Segment Tax: 100% Railroad Response
Upper Mississippi	$170,151	$1,673,701	$1,698,429	$1,720,909
Middle Mississippi	187,543	1,493,134	1,504,670	1,570,920
Lower Mississippi	910,181	1,470,425	1,474,863	1,500,244
Arkansas	10,530	255,240	255,240	255,240
Ohio	180,765	108,132	108,132	98,190
Missouri	119,003	816,754	826,407	1,042,725
Illinois	52,489	247,336	247,336	247,336
Total	1,630,662	6,064,772	6,115,077	6,435,564

Table 54

Total Revenue Collected by Mode under
Each 1990 User Charge Senario

Mode	Base	Fuel Tax: 38.1¢ per Gallon	Segment Tax: No Railroad Response	Segment Tax: 50% Railroad Response	Segment Tax: 100% Railroad Response
Rail	$184.0	$187.6	$190.6	$192.3	$192.0
Truck	50.5	51.7	52.1	52.0	51.8
Barge	63.9	59.3	56.0	56.2	58.4
Pipeline	12.4	12.4	12.6	12.6	12.6
Total	310.8	311.0	311.2	313.2	314.7

Table 55

Price Elasticities of Demand for 1990 Fertilizer Barge Service from New Orleans, Louisiana and Central Florida to River Destinations under a 38.1¢ per Gallon Fuel Tax and a 100% OMRC Recovery Segment Tax

River Destination	Urea from New Orleans		Ammoniated Phosphates from New Orleans		Triple Superphosphate from Florida		Nitrogen Solutions from New Orleans	
	Fuel	Segment	Fuel	Segment	Fuel	Segment	Fuel	Segment
Friars Point, Mississippi	0.0	0.0	0.0	-15.17	0.0	0.0	-	-
Barfield, Arkansas	0.0	0.0	0.0	0.0	0.0	0.0	-	-
Birds Point, Missouri	-	-	-	-	-	-	0.46	0.87
Chester, Illinois	0.0	0.0	-87.20	-15.13	0.0	0.0	-	-
Herculaneum, Missouri	-	-	-	-	-	-	0.0	0.0
Granite City, Illinois	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Palmyra, Missouri	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Burlington, Iowa	0.0	0.0	0.0	0.0	0.0	0.0	10.27	10.05
Clinton, Iowa	0.16	1.90	-0.17	-1.40	0.0	0.0	0.0	0.0
Prairie du Chien, Wisconsin	0.0	0.0	0.0	0.0	0.0	0.0	1.32	2.38
Pine Bend, Minnesota	-0.10	0.31	-0.35	-0.03	72.86	8.07	1.63	1.35
Catoosa, Oklahoma	0.0	0.0	0.0	0.0	0.0	0.0	-	-
South Point, Ohio	-	-	-	-	-	-	0.0	0.0

Table 55--Continued

River Destination	Urea from New Orleans		Ammoniated Phosphates from New Orleans		Triple Superphosphate from Florida		Nitrogen Solutions from New Orleans	
	Fuel	Segment	Fuel	Segment	Fuel	Segment	Fuel	Segment
Cincinnati, Ohio	0.0	0.0	0.0	-5.18	0.0	0.0	0.0	0.0
Owensboro, Kentucky	0.0	19.79	0.0	-4.32	0.0	0.0	0.0	0.0
Louisville, Kentucky	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Boonville, Missouri	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kansas City, Kansas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mound City, Missouri	0.0	0.0	0.0	0.0	0.0	0.0	-	-
Nebraska City, Nebraska	-	-	-	-	-	-	0.0	0.0
Council Bluffs, Iowa	18.64	8.05	-2.01	-0.94	0.0	19.63	-	-
Sioux City, Iowa	0.0	0.0	2.76	4.25	0.0	18.40	0.0	0.0
Meredosia, Illinois	-	-	-	-	-	-	0.0	0.0
Pekin, Illinois	0.0	0.0	0.0	0.0	0.0	0.0	-0.14	-0.15
Joliet, Illinois	0.0	0.0	0.0	-3.60	0.0	0.0	9.61	9.93
Calumet City, Illinois	0.0	-6.08	0.0	4.46	0.0	0.0	-	-

elasticities depict the overall unresponsiveness of the fertilizer industry to the basic waterway user charges. Also, revealed are various substitutions and shifts in the demand for fertilizer barge services which are discussed in detail later. Finally, Table 56 presents price elasticities of demand by river.

Referring back to Table 43, we find that as the user charge becomes more severe, more barge traffic is lost to competing modes. Under the 38.1¢ per gallon fuel tax, 347,072 tons of fertilizer are lost, while under the segment tax, 462,959 tons are lost to competing modes. Conversely, total barge traffic increases as railroad response rises for a given user charge tax. In the 100% OMRC recovery segment tax, 50% railroad response case, 4,258 tons of fertilizer traffic shift back to the barge mode, while in the 100% OMRC recovery segment tax, 100% railroad response case, 74,565 tons of fertilizer shift back to the barge mode.

Table 57 presents total barge traffic by river, while Tables 58 through 61 report barge traffic by fertilizer and river for each 1990 user charge scenario. As with 1985 user charges, individual rivers do not necessarily behave in the same manner as total barge shipments. For example, ammoniated phosphate shipments rise as the user charge becomes more severe and falls as railroad response increases. Therefore, ammoniated phosphates reacts to 1990 user charges in exactly the opposite way that total barge shipments react. These and other implications of each 1990 waterway user charge are discussed below.

Table 56

Price Elasticities of Demand for 1990 Fertilizer Barge Service from New Orleans, Louisiana and Central Florida to Each River Segment under a 38.1¢ per Gallon Fuel Tax and a 100% OMRC Recovery Segment Tax

River Segment	Urea from New Orleans		Ammoniated Phosphates from New Orleans		Triple Superphosphate from Florida		Nitrogen Solutions from New Orleans	
	Fuel	Segment	Fuel	Segment	Fuel	Segment	Fuel	Segment
Upper Mississippi	-0.002	0.54	-0.25	-0.23	19.80	3.34	3.73	4.28
Middle Mississippi	0.0	0.0	-2.43	-0.42	0.0	0.0	0.19	0.37
Lower Mississippi	0.0	0.0	0.0	-5.44	0.0	0.0	0.0	0.0
Arkansas	0.0	0.0	0.0	0.0	0.0	0.0	-	-
Ohio	0.0	2.14	0.0	-4.62	0.0	0.0	0.0	0.0
Missouri	18.64	8.05	0.80	1.17	0.0	19.36	0.0	0.0
Illinois	0.0	-1.94	0.0	0.05	0.0	0.0	2.96	3.05

Table 57

Projected Total Tons of Fertilizer Shipped by Barge to River Segments under Each 1990 User Charge Scenario

River Segment	Base	Fuel Tax: 38.1¢ per Gallon	Segment Tax: No Railroad Response	Segment Tax: 50% Railroad Response	Segment Tax: 100% Railroad Response
Lower Mississippi	61,638	61,638	80,850	61,638	61,638
Middle Mississippi	411,751	419,137	419,137	419,137	408,148
Upper Mississippi	1,726,865	1,568,778	1,501,613	1,520,827	1,572,984
Arkansas	90,000	90,000	90,000	90,000	90,000
Ohio	756,217	756,218	822,500	822,500	756,218
Missouri	759,181	734,895	541,527	545,785	641,206
Illinois	798,878	626,790	685,942	685,942	685,942
Total	4,604,530	4,257,456	4,141,569	4,145,829	4,216,136

Table 58

Projected Tons of Nitrogen Solutions Shipped by Barge to River Segments under Each 1990 User Charge Scenario

River Segment	Base	Fuel Tax: 38.1¢ per Gallon	Segment Tax: No Railroad Response	Segment Tax: 50% Railroad Response	Segment Tax: 100% Railroad Response
Upper Mississippi	292,703	134,618	109,618	109,618	109,618
Middle Mississippi	116,503	112,900	112,900	112,900	112,900
Lower Mississippi	0	0	0	0	0
Arkansas	--	--	--	--	--
Ohio	432,500	432,500	432,500	432,500	432,500
Missouri	0	0	0	0	0
Illinois	365,499	193,411	193,411	193,411	193,411
Total	1,207,205	873,429	848,429	848,429	848,429

Table 59

Projected Tons of Urea Shipped by Barge to River Segments under Each 1990 User Charge Scenario

River Segment	Base	Fuel Tax: 38.1¢ per Gallon	Segment Tax: No Railroad Response	Segment Tax: 50% Railroad Response	Segment Tax: 100% Railroad Response
Upper Mississippi	506,307	506,306	447,154	447,155	447,155
Middle Mississippi	103,911	103,911	103,911	103,911	103,911
Lower Mississippi	0	0	0	0	0
Arkansas	0	0	0	0	0
Ohio	164,921	164,922	132,681	132,681	153,168
Missouri	17,864	10,074	0	0	0
Illinois	129,365	129,365	188,517	188,517	188,517
Total	922,368	914,578	872,263	872,264	892,751

Table 60

Projected Tons of Ammoniated Phosphates Shipped by Barge to River Segments under Each 1990 User Charge Scenario

			Segment Tax:		
River Segment	Base	Fuel Tax: 38.1¢ per Gallon	No Railroad Response	50% Railroad Response	100% Railroad Response
Upper Mississippi	890,657	896,162	939,287	958,500	979,013
Middle Mississippi	191,337	202,326	202,326	202,326	191,337
Lower Mississippi	61,638	61,638	80,850	61,638	61,638
Arkansas	90,000	90,000	90,000	90,000	90,000
Ohio	158,796	158,796	257,319	257,319	170,550
Missouri	721,683	705,187	541,527	541,527	621,572
Illinois	304,014	304,014	304,014	304,014	304,014
Total	2,418,125	2,418,123	2,415,323	2,415,324	2,418,124

Table 61

Projected Tons of Triple Superphosphate Shipped by Barge to River Segments under Each 1990 User Charge Scenario

River Segment	Base	Fuel Tax: 38.1¢ per Gallon	Segment Tax: No Railroad Response	Segment Tax: 50% Railroad Response	Segment Tax: 100% Railroad Response
Upper Mississippi	37,198	31,692	5,554	5,554	37,198
Middle Mississippi	0	0	0	0	0
Lower Mississippi	0	0	0	0	0
Arkansas	0	0	0	0	0
Ohio	0	0	0	0	0
Missouri	19,634	19,634	0	4,258	19,634
Illinois	0	0	0	0	0
Total	56,832	51,326	5,554	9,812	56,832

Analysis of the 38.1¢ per gallon fuel tax

The results of the 38.1¢ per gallon fuel tax for 1990 are very similar to the 32.4¢ per gallon fuel tax for 1985. Nitrogen solutions are most severely affected with 333,776 fewer tons shipped by barge due to additional nitrogen solutions manufacturing in the Midwest. The upper Mississippi River loses 142,450 tons to truck and 15,635 tons to pipeline, the middle Mississippi River loses 3,603 tons to pipeline, and the Illinois River loses 172,088 tons to truck. Other minor shifts in nitrogen solutions marketing occur within the truck, rail, and pipeline modes with these shifts confined to the Midwest.

Nitrogen Solutions market pattern shifts affect other commodities also. Ammonium nitrate supplies are adequate to meet the increase in Midwestern nitrogen solutions marketing, but urea supplies are not sufficient. Thus, 100,161 additional tons of urea are shipped by rail from other Midwestern supply points for nitrogen solutions manufacture than in the base scenario. Other small shifts occur in urea marketing, some as far away from the Midwest as Texas. However, no additional urea is barged on the upper Mississippi River as in the 32.4¢ per gallon fuel tax scenario. Finally, 7,790 tons of urea are forced off the Missouri River at river warehouses operating at capacity by ammoniated phosphates.

Under the 38.1¢ per gallon fuel tax, the same total tonnage of ammoniated phosphates is shipped by barge; however, a few minor shifts occur between rivers. It is now more economical if 16,496 fewer tons of ammoniated phosphates are shipped by barge on the Missouri River with

5,506 and 10,989 tons transferred to the upper Mississippi and middle Mississippi Rivers respectively. Ammoniated phosphates are now shipped by rail from Florida to those demand regions formerly receiving ammoniated phosphates by barge from New Orleans. Finally, since some warehouses on the upper Mississippi River were operating at capacity in the base scenario, the increase in ammoniated phosphate barge traffic forces 5,506 tons of triple superphosphate off the upper Mississippi River.

Analysis of the 100% recovery segment tax

As with 1985 user charges, the impact of the 100% OMRC recovery segment tax is more pronounced than the 38.1¢ per gallon fuel tax. Nitrogen solutions react somewhat differently under the segment tax than under the fuel tax. This was not the case for 1985 user charges. Under the 1990 segment tax, 358,776 tons of nitrogen solutions are lost to competing modes, 25,000 tons more than under the fuel tax scenario. These shifts induce several other minor shifts between rail and pipeline marketing of nitrogen solutions in the Midwest. Also, as in the fuel tax scenario, an additional 100,161 tons of urea are shipped by rail from Midwestern supply points to manufacture nitrogen solutions.

Total barge shipments of ammoniated phosphates fall only 2,802 tons, but considerable shifting takes place between rivers. The Missouri River shifts 180,155 tons to the rest of the inland waterway system; 19,212, 10,989, 48,631, and 98,523 tons to the lower Mississippi, middle Mississippi, upper Mississippi, and Ohio Rivers, respectively. As under the 1985 100% OMRC recovery segment tax, ammoniated phosphates barge traffic does not shift because barge rates are more expensive than rail rates, but rather, greater savings are realized if ammoniated phosphates are barged elsewhere.

Again, since many warehouses on the middle Mississippi, Ohio, and Illinois Rivers are operating at capacity in the base scenario, increase in ammoniated phosphate traffic forces out 32,241 and 17,864 tons of urea on the Ohio and Missouri Rivers. This causes several minor shifts in rail and truck marketing of urea in the Midwest. Also, 59,153 tons of urea shift from the upper Mississippi to the Illinois River under the segment tax.

Finally, triple superphosphate barge rates are now more expensive than rail rates, thus total triple superphosphate barge shipments drop 51,278 tons; 31,644 on the upper Mississippi and 19,634 on the Missouri Rivers.

Analysis of the 100% OMRC recovery segment tax, 50% railroad response

This discussion describes the impact of a 50% railroad response to a 100% OMRC recovery segment tax. All references to changes or shifts in quantities of fertilizer shipped are with respect to the 100% OMRC recovery segment tax computer solution.

As with the 1985 50% railroad response scenario, the effects are quite limited, since the barge industry regains less than 1.0% of total traffic lost due to the segment tax. Examination of individual fertilizer response reveals that ammonium nitrate and nitrogen solutions experience no change in their marketing patterns, while ammoniated phosphates, urea, and triple superphosphate experience only minor changes.

Under the 50% railroad response scenario, it is now more economical to shift 19,212 tons of ammoniated phosphates from the lower Mississippi to the upper Mississippi River. This shift induces other minor rail and truck shifts in the Midwest. Also, since some warehouses on the upper Mississippi River are operating at capacity in the segment tax scenario with no railroad response, an equivalent amount of urea shifts to other warehouses on the upper Mississippi River, prompting a few adjustments in rail and truck marketing of urea in the Midwest.

Finally, under 50% railroad response, 4,258 tons of triple superphosphate on the Missouri River shift back to barge from rail due to more favorable barge rates.

Analysis of the 100% OMRC recovery segment tax, 100% railroad response

This discussion describes the impact of a 100% railroad response to a 100% OMRC recovery segment tax. All references to changes or shifts in quantities of fertilizer are with respect to the 100% OMRC recovery segment tax computer solution.

The 100% railroad response scenario produces more marketing changes than the 50% railroad response scenario as exhibited by the fact that the barge industry regains over 16% of total barge traffic lost due to the segment tax. Again, ammonium nitrate and nitrogen solutions experience no changes, but some shifts occur in ammonium nitrate, urea, and triple superphosphate marketing patterns. Total barge shipments of ammoniated phosphates increase by only 2,801 tons, but many shifts occur between rivers. The lower Mississippi, Ohio, and middle Mississippi Rivers lose 19,212, 86,769, and 10,989 tons, while the upper Mississippi and Missouri Rivers gain 39,725, and 80,045 tons of ammoniated phosphates, respectively. Of the 119,770 tons of ammoniated phosphates gained by the upper Mississippi and Missouri Rivers, only 2,801 tons are from railroads. These changes in barge marketing induce numerous other minor shifts in rail and truck marketing of ammoniated phosphates in the Midwest.

The 100% railroad response makes some triple superphosphate barge rates less expensive than rail rates, thus 31,644 tons and 19,634 tons shift from rail to barge on the upper Mississippi and Missouri Rivers. Other minor changes in Midwestern rail and truck marketing of triple superphosphate occur also.

SUMMARY AND CONCLUSIONS

Waterway user charges are projected to have very little impact on the fertilizer industry. Total fertilizer barge traffic is projected to drop only 7.8% under a 100% recovery segment tax and only 3.0% under a 32.4¢ per gallon fuel tax during 1985. By 1990, normal growth in domestic agricultural fertilizer demand more than offsets this loss in barge traffic. Since most barged fertilizer originates in New Orleans and many fertilizer barge rates are lower than rail rates from New Orleans, higher user charge tax levels than those modelled in this study would be required to divert additional traffic.

Even though the overall impact of waterway user charges is small, these impacts are not uniform across all rivers. For example, during 1985 it is projected the Missouri River will lose over one-third of its traffic under a segment tax user charge, while other rivers such as the Ohio actually experience an increase in barge traffic by picking up the Missouri River's lost traffic. The 1985 fuel tax induces similar types of changes in fertilizer marketing patterns. However, these marketing changes are not as prominent under the fuel tax since the fuel tax modelled in this study is less severe than the segment tax. Diverse user charge impacts are observed across fertilizers as well. In the previous segment tax example, some urea traffic is forced off the Ohio to make warehouse room for the ammoniated phosphate traffic shifting from the Missouri River to the Ohio River. Thus, predicting how individual river segments or fertilizers will react to user charges by deduction from the overall reaction of the fertilizer industry may lead to erroneous conclusions. Waterway user charge impacts for specific cases can be accurately projected only by carefully studying the model's results. Finally, projected user charge impacts are quite consistent between 1985 and 1990, thus indicating that the fertilizer industry exhibits a strong temporal stability when subject to user charge taxes.

Since it has been assumed that 100% of the user charge is passed on in the form of higher barge rates, it is thought the short term impacts of user charges on the fertilizer industry are exaggerated. In reality, barge operators may choose to absorb part or all of the user charge to retain customers and to keep their barge equipment operating. As long as the barge operator recovers his variable costs and any portion of his fixed costs, he can remain in business. Thus, the barge operator may adopt the strategy of passing the user charge on to those customers he considers to not be modal preference sensitive to changes in transportation rates, or who are captive to the barge mode. Barge operators will be required to determine how much of the user charge to pass on to each consumer so they can retain their share of the market while also maintaining an acceptable rate of return on their investment. In response, competing modes such as rail, must determine how they will react to higher barge rates. If railroad equipment utilization is low, they may elect to not react at all. However, if equipment utilization is high, they may choose to act in a manner similar to the barge industry by raising rates only in those areas not sensitive to transportation rate changes. Keep in mind that any change in railroad rates is subject to the provisions of the Staggers Act. Railroads will be required to justify rate increases relative to only their own costs without regard to other modes' rates.

In evaluating the impacts of waterway user charges, an attempt should be made to determine if one user charge is preferred over the other and for what reasons. To aid in this evaluation, the following criteria have been established to measure and compare each user charge.

- o The user charge should promote stability such that barge operators, fertilizer shippers, and consumers are able to accurately estimate the amount of tax they will have to pay, so they can plan future operations and investments.
- o The user charge should encourage efficient use of barge equipment and the inland waterway system by minimizing cross subsidization of high cost river segments by low cost segments.
- o The user charge should make it easy to identify those operators who are not paying the tax so penalties can be assessed.
- o The user charge should be easy and efficient to administer.
- o The user charge should be flexible such that when additional maintenance and construction costs are incurred, they can be easily incorporated into the tax.

The fuel tax has an advantage over the segment with respect to the first criteria, stability. If additional construction or maintenance costs are incurred, the segment tax assesses all of these costs to users of that river segment. These additional taxes, if large enough, could force users of this river segment to dramatically alter their future investment and operation plans. However, under a fuel tax these new costs are distributed to all users of the entire inland waterway system, minimizing the shock to the users of the river segment incurring the additional cost. Thus, the fuel tax satisfies the stability criteria better than the segment tax.

On the next point, efficiency, the segment tax performs better than the fuel tax. The segment tax is economically efficient in the sense that only those who use the investments of a river segment pay for them. This is not the case with the fuel tax. Since a strong relationship does not exist between fuel consumption and construction, operation, maintenance, and repair costs, the fuel tax introduces a considerable amount of cross subsidization to the inland waterway system. Low cost river segments users are forced to pay for some of the investments on high cost river segments, thereby reducing the overall efficiency of the inland waterway system.

The segment tax is also superior to the fuel tax on the third point, penalty assessment. There are numerous ways to avoid paying a fuel tax, especially when the responsibility for fuel consumption reporting resides with the barge operator. However, it would be much more difficult to evade paying a segment tax if the Army Corps of Engineers monitored all barge movements at each locking facility. Pertinent information required for tax assessment could easily be collected while a barge tow is locked through without disrupting the lockage operation. Calculating and billing the tax to each operator becomes a simple task easily performed by computer.

It appears that neither tax can claim to win the fourth point, ease of administration. Numerous problems are associated with administering both user charges. Under a fuel tax, developing an accurate non-evadable reporting mechanism is difficult enough, but providing adequate ways for firms to receive credit for non-taxable fuel consumption just adds to the complexity of the mechanism. Examples of non-taxable fuel uses are mid-stream cargo transfer and fueling operations, electricity generation, heating, recreation, dredging, and salvage and repair operations. Also, many barge shipments traverse both the taxable (below Baton Rouge, Louisiana on the lower Mississippi River) and non-taxable (above Baton Rouge) portions of the inland waterway system during a single tow operation. If the fuel tax is collected at the pump similar to state and federal highway fuel taxes, a method must be developed to determine how much of a rebate the barge operator should receive for fuel consumed on the non-taxable portion of the inland waterway system. On the other hand, if the fuel tax is collected from the barge operator, a mechanism must be developed to estimate how much fuel is exempt from tax due to non-taxable river segment operations. The segment tax has a different set of administration problems. The approach of having the Army Corps of Engineers monitor barge activity at each lock works well on most river segments. However, some river segments such as the lower Mississippi and Missouri Rivers have no locks, making it impossible to monitor barge traffic. Barge operator reporting, though less reliable, would be required for all shipping on these segments. Thus, both taxes have serious administration problems creating a standoff on this point.

Finally, both taxes appear to be flexible and responsive to changes in construction and operation plans of the Army Corps of Engineers. Additional analysis would be required for either user charge to set new tax rates which will recover 100% of operation, maintenance, repair, and construction costs. The complexity of the analysis required for each user charge does not vary significantly, giving neither tax an advantage on this point.

Of the five criteria used to evaluate waterway user charges, the segment tax outperforms the fuel tax two to one, with two points even. Thus, neither tax has conclusively demonstrated its superiority over the other. Additional criteria or weighting criteria by their importance might produce more definitive results. However at this stage, the issue of which user charge out performs the other is unresolved with respect to the fertilizer industry.

Even though we have not been able to objectively ascertain which type of user charge is superior, each user of the inland waterway system may have a well defined preference for a particular user charge. If the user produces, ships, or consumes liquid fertilizers, and operates on low cost river segments, he will prefer the segment tax. However, if he resides on a high cost river segment he will prefer a fuel tax since users of other segments will be subsidizing his operations. If the user deals with dry fertilizer, he will prefer the fuel tax regardless of which segment he is operating on since the fuel tax, as modelled in this study, is considerably lower than the segment tax. The situation becomes even more confusing if a waterway user is involved with both dry and liquid fertilizers or operates on more than one river segment. In these instances, no clear-cut user charge preference can be defined. Each situation must be analyzed on an individual basis.

This study has examined in detail the impacts of waterway user charges on fertilizer producers, shippers, and consumers. In most cases, the fertilizer industry and farmers are better-off under a fuel tax than a segment tax, as modelled in this study. However, conclusions drawn from this analysis apply only to the fertilizer industry. As Congress deals with the user charge issue, it will be concerned with all sectors of the economy. Thus, Congress must analyze user charge impacts for all barge shipped commodities to determine which user charge is superior.

APPENDIX

Maps 2 through 21 present detailed fertilizer shipping patterns projected by the computer model. One map is given for each valid fertilizer-mode combination for the 1985 base scenario in which no user charge taxes are assessed. Maps for other user charge scenarios were also generated, but they vary only slightly from the base solution under even the most severe user charge tax. Thus, maps for other 1985 scenarios are not presented to avoid redundancy. Likewise, maps are not presented for 1990 scenarios since 1985 and 1990 shipping patterns are very similar, and user charges have very little impact on 1990 base solution shipping patterns.

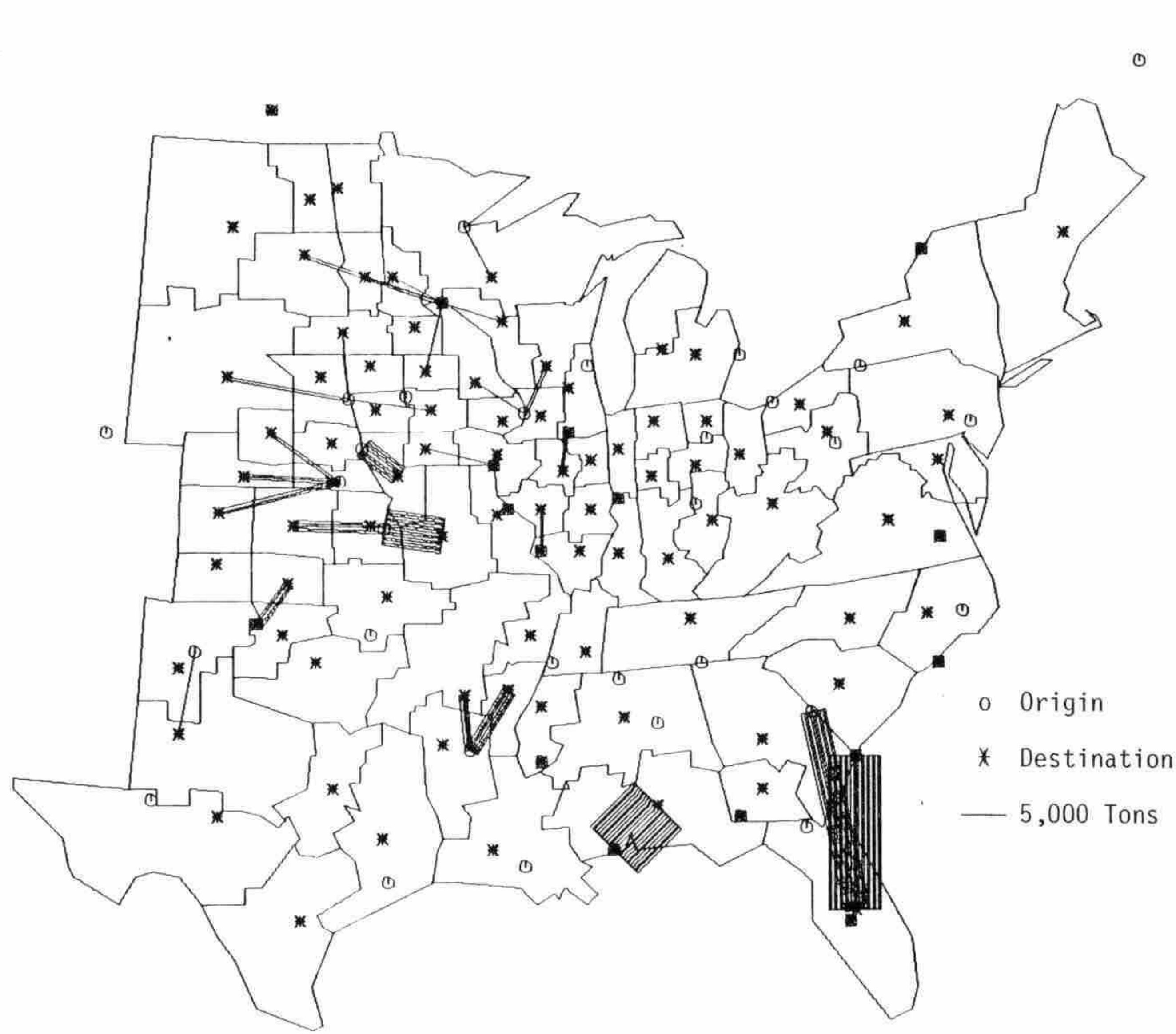
These maps were generated via SIMPLOTTER plotting routines called by a user written PL/I computer program. This program accessed data generated by the Mathematical Programming System - Extended (MPSX) which was used to impliment the model used in this study. The plotting program modified the MPSX fertilizer shipping pattern output to fit a predefined coordinate system of the United States. Finally, these shipping patterns were transferred to magnetic tape and plotted on a CalComp Digital Incrimental Plotter with a resolution of 1/100 inch.

Map 2. Projected 1985 rail shipments of urea assuming no user charge tax

Map 3. Projected 1985 truck shipments of urea assuming no user charge tax

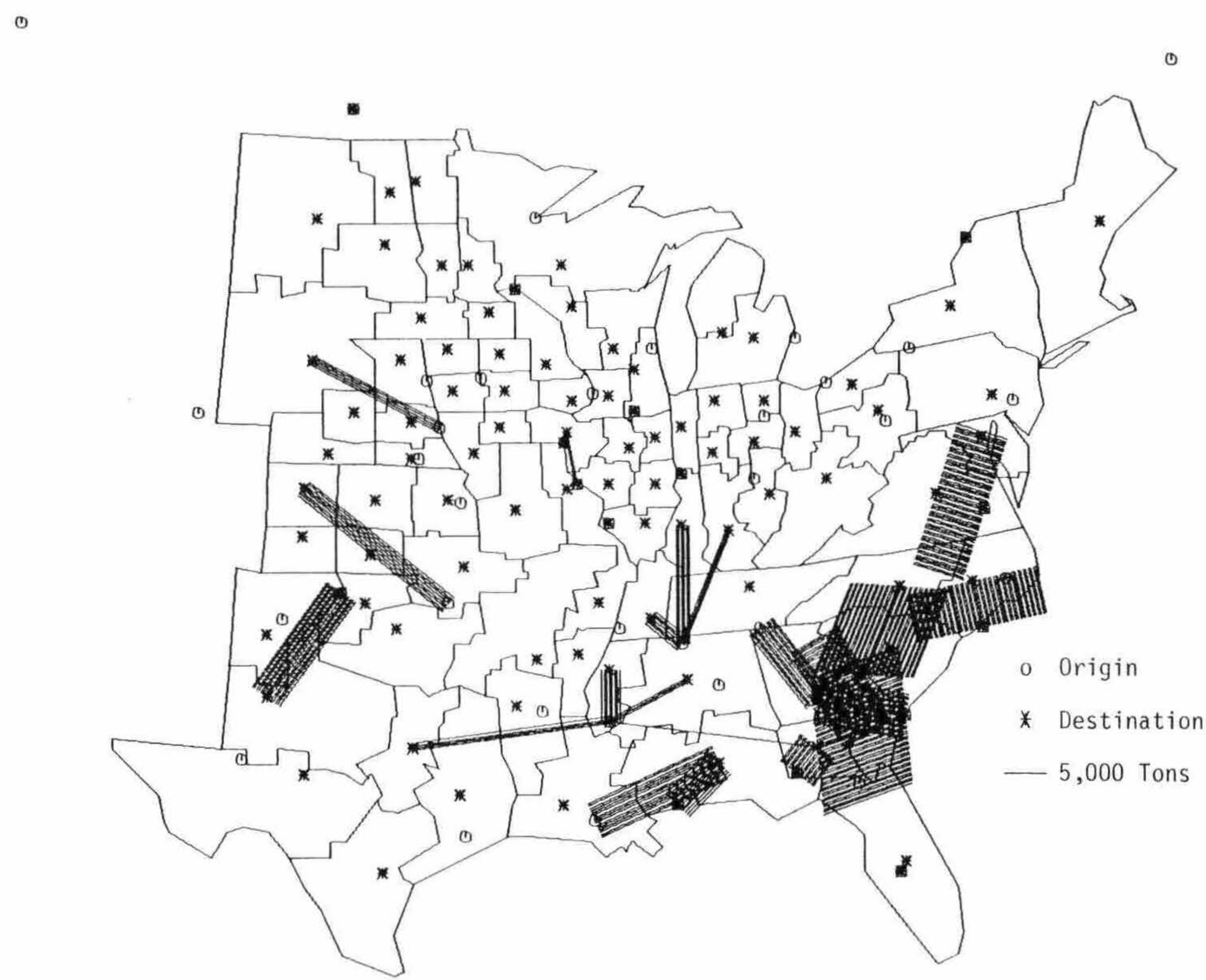
Map 4. Projected 1985 barge-rail shipments of urea assuming no user charge tax

Map 5. Projected 1985 barge-truck shipments of urea assuming no user charge tax

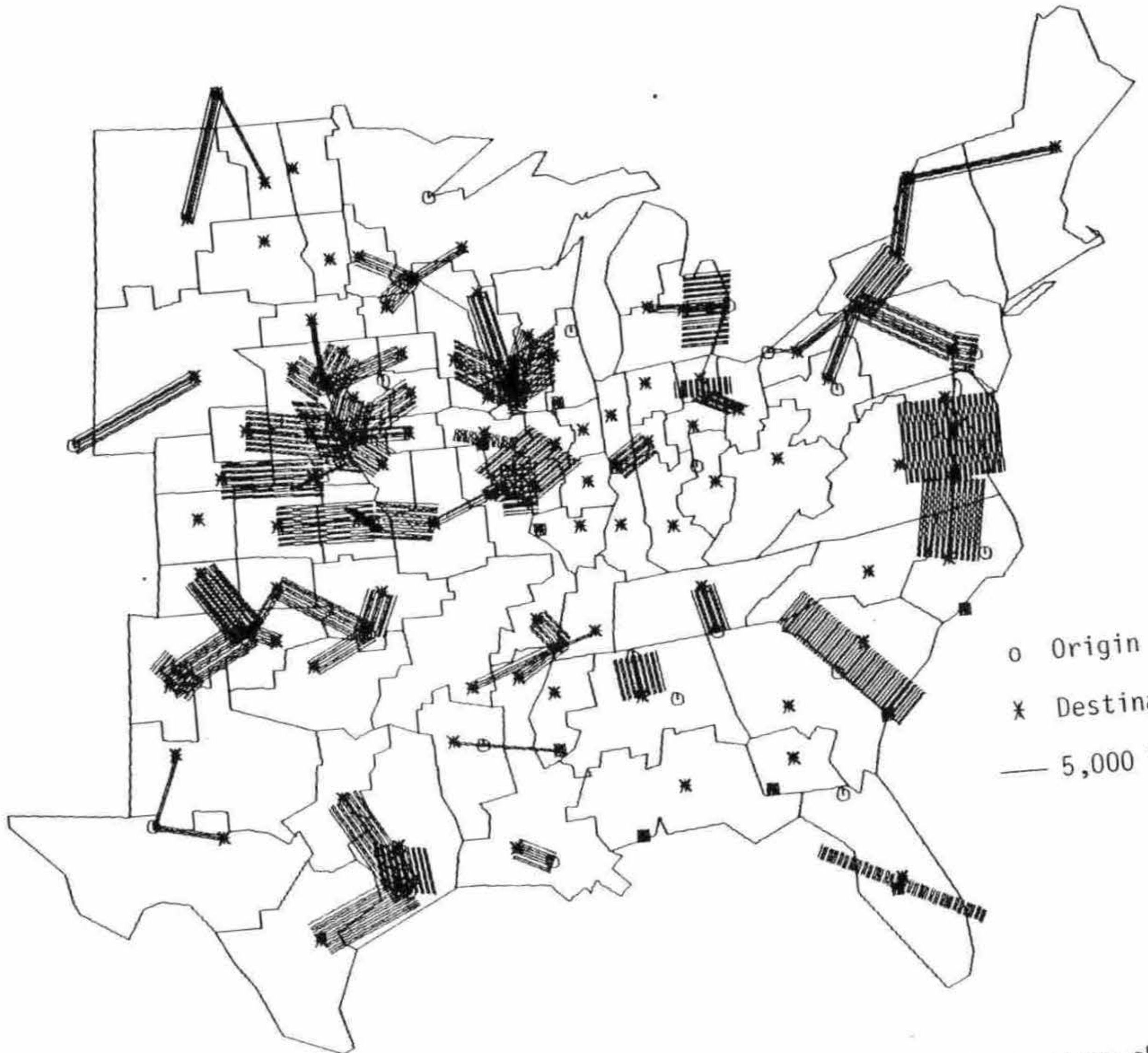


Map 6. Projected 1985 rail shipments of ammonium nitrate assuming no user charge tax

Map 7. Projected 1985 truck shipments of ammonium nitrate assuming no user charge tax



Map 8. Projected 1985 rail shipments of nitrogen solutions assuming no user charge tax



Map 9. Projected 1985 truck shipments of nitrogen solutions assuming no user charge tax

Map 10. Projected 1985 barge-rail shipments of nitrogen solutions assuming no user charge tax

Map 11. Projected 1985 barge-truck shipments of nitrogen solutions assuming no user charge tax

Map 12. Projected 1985 pipeline-rail shipments of nitrogen solutions assuming no user charge tax

Map 13. Projected 1985 pipeline-truck shipments of nitrogen solutions assuming no user charge tax

Map 14. Projected 1985 rail shipments of ammoniated phosphate assuming no user charge tax

Map 15. Projected 1985 truck shipments of ammoniated phosphate assuming no user charge tax

Map 16. Projected 1985 barge-rail shipments of ammoniated phosphate assuming no user charge tax

Map 17. Projected 1985 barge-truck shipments of ammoniated phosphate assuming no user charge tax

Map 18. Projected 1985 rail shipments of triple superphosphate assuming no user charge tax

Map 19. Projected 1985 truck shipments of triple superphosphate assuming no user charge tax

Map 20. Projected 1985 barge-rail shipments of triple superphosphate assuming no user charge tax

Map 21. Projected 1985 barge-truck shipments of triple superphosphate assuming no user charge tax

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